A TEXT-BOOK

OF

RACTURES AND DISLOCATIONS

ITH SPECIAL REFERENCE TO THEIR PATHOLOGY DIAGNOSIS AND TREATMENT

BY

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TO

EDWARD WYLLYS ANDREWS, A.M., M.D., F.A.C.S.

GENTLEMAN, MASTER SURGEON AND FRIEND

THIS BOOK

IS RESPECTFULLY DEDICATED BY

THE AUTHOR

PREFACE.

In the preparation of this work the author has carefully culled from the literature the information which seemed most helpful and with it has combined his own ideas and experience in order to cover the field and to present a clear understanding of this important branch of surgery. Much of the clinical and all of the statistical material has been obtained at the Cook County Hospital, Chicago. Although the author has personally performed the labor of writing the text and gathering the illustrations, for all of which he alone is responsible, he has been fortunate in receiving the helpful coöperation of his colleagues in the hospitals with which he is connected and of members of the Chicago Surgical Society. He wishes here to express his appreciation of their kindness if at any place in the text he has failed to make more specific acknowledgment.

It has come to be appreciated in all branches of medical teaching and research that a basic knowledge of pathology is of prime importance, so it is believed that clear conception of osseous injuries and their repair is essential to an understanding of fractures. Better treatment results. For this reason the author has selected examples of different types of usual fracture pathology and endeavored to bring them before the reader's eye by means of line drawings which illustrate the essential points. Every illustration of this character is a careful reproduction of a tracing made from a *Roentgenogram of an actual case*. The Artist, Mr. Streedain, and the author have worked for nearly two years preparing these drawings, checking and rechecking each one until it conveyed the author's conception of the lesion. No one can read all roentgenograms with positive assurance. The author's obligations to Dr. Blaine, Roentgenologist to the Cook County Hospital, for his friendly coöperation in this part of the work are gratefully recorded. The Artist has attempted to differentiate the shadows of bones more distant from the observer by lighter lines, and where two shadows overlap has indicated the one more remote by dotted lines. Cutaneous landmarks, lines of incisions with skin clips and plaster dressings have been occasionally indicated for obvious reasons.

It has seemed unwise to cumber the pages with statistical charts and tables recording all cases of fractures studied by the author; but he has not failed to incorporate freely in the text deductions from many such tables which have been accurately compiled for his private use. The nomenclature employed accords with that used in the Howden edition of *Gray's Anatomy*.

The author wishes to thank the Publishers for making the book possible. He is also under obligations to his various House Surgeons and to those who have helped in the mechanical preparation of the text. Dr. J. J. Andrews and D. L. have aided greatly by friendly criticism.

K. S.

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FRACTURES AND DISLOCATIONS.

CHAPTER I.

BONE.

Physiology and Physics—Regeneration—Callus Formation—Callus in Joint Fractures—Effects on Callus of Early Motion, Massage, and Foreign Bodies—Bone Transplantation and Fate of Transplants—Bone Repair in Open Fractures and Post-operatively—Clinical Course of Fracture.

FRACTURES and dislocations deal primarily with bone, and the student and practitioner should have intimate knowledge of the details of osseous growth and structures. This chapter aims to deal with the general questions involving bone, largely from a practical and clinical standpoint, because elementary facts concerning bone and its repair become distorted when practical application to fracture is needed.

Anatomical text-books give information in regard to the formation of bone, its deposition in cartilage and membrane, and the present writer has no intention of reiterating. Osseous tissue, the hardest tissue of the human body, is not to be considered as an inert framework on which other important organs and tissues are draped. It possesses elasticity and toughness—that is, power to resist stress and strain—and is consequently governed by the physical laws of elastic bodies subject to these forces. Fortunately for animals, and especially for men, bones are also influenced by other factors which govern their appearance, strength, power of recuperation, and regeneration. An analysis from the standpoint of composition, with bone considered as a physical combination of substances, demonstrates that the earthy or hard properties are furnished by calcium phosphate, carbonate, and fluoride, with the addition of some magnesium phosphate. These salts compose about 66 per cent. of the total bone weight. Adolescent bones contain a smaller percentage of salts, senile bones, a greater percentage. The calcium balance concerns all the skeletal tissues in the building-up and tearing-down processes. There is probably a continuous flow of calcium salts both to and from the bone, the amount dependent on the available supply in the food intake and on the metabolic processes, a matter of such intricate mechanism that it is not thoroughly understood. Under ordinary conditions of food and metabolism the supply is sufficient to meet all demands; when the

diet is deprived of calcium salts there is absorption from the bones. This loss by the bones first affects those which can spare calcium best without affecting their tensile strength, namely, the sternum, skull, ribs, etc. Under some conditions the amount of ingested calcium is by no means a measure of that used in bone reconstruction, because other tissues demand these salts. In rickets and osteomalacia there is probably such a *diversion* to other structures, and *perversions* with skeletal deformities exist in diseases of the pituitary body and disease or congenital absence of the thyroid or thymus.

While we accept this information as all important in its bearing on the rigidity of osseous material, we must not lose sight of the fact that bone is a *living* and *growing tissue*. It varies in size and shape from time to time; it is built up and torn down much as are the skin and epithelial surfaces which are constantly undergoing repair; and it is shaped by the plastic power of growth and force, as are the soft tissues. Wolff's law states the idea thus: the shape of bones is determined by conditions of reactions of bones in structure and shape to the body weight and to stress and strain of muscular action.[1]

Life and growth of bone are provided for by its division into three parts: the covering or periosteum, the compact tissue or dense ivory-like substance, and the cancellous tissue or softer part found within the compact. Blood supply is rich, furnished by the periosteum, with its vessels penetrating into the compacta and cancellous tissue, and the nutrient and epiphyseal arteries which supply the softer content within the hard outer layer. Blood supply is of the greatest importance in bone regeneration and growth, as it is in any tissue, another factor too frequently overlooked. There are also nerves and lymphatics in bone, delicate and important structures which perform their functions inside the hard covering about them. These functions are easily terminated when the covering is greatly disturbed, as in fracture or other injuries.

It has been determined that the proportion of earthy salts in the bone matrix is a sensitive indication of the life of the bone, that is, of its age or condition of health. When bone is diseased or injured or deprived of its normal function of stress and strain from weight-bearing and muscular action, an atrophy develops within it. The proportion of the salts in its composition is disturbed, and early evidence of this disturbance is found in the character of the shadow cast on the sensitized plate when an exposure is made to the Roentgen rays. Corson[2] has stated that the Roentgen-ray shadow of an element is distinctly proportional to its atomic weight. Calcium with an atomic weight of 40 makes a denser shadow than magnesium, weight 24, and because the latter represents only a small percentage of the earthy salts, the main role in shadow density is played by the calcium salts. The best example of this truth lies in the fact that recent callus casts no shadow. No calcifying salts have been deposited. Bone

[1] Tubby, Brit. Med. Jour., 1908, vii, 25.

[2] Ann. Surg., li, 289.

atrophy may be the result of a neurotrophic process, or a senile osteoporosis, or of bone cysts affecting small areas, or the hypertrophic syphilitic conditions which leave pits of ulcerating gummatous areas. It also occurs after muscular trauma and inactivity, poliomyelitis or the muscular dystrophies, cerebral palsies, etc. Sensitive bone may show atrophy after nerve injury which involves itself directly or its surrounding soft parts. This pathological fact is of practical bearing in some cases of non-union, or in refracture following clean operative fixation, or in removal of tibial crests for autogenous splints, which may be the result of such nerve disturbance.[1] (See Chapter on Operative Treatment.)

Cancellous and compact tissue are much alike, the former being more porous. When it is necessary in body economy that great weight and much stress should be sustained, a bone is composed of more elastic cancellous tissue and less friable and rigid compact tissue. The calcaneus and vertebræ are excellent examples. They have a mere shell of compact tissue about them. Great rigidity and stiffness needed in the limbs is shown by the increased amount of the compact tissue in the shafts of the femur, tibia, humerus, and forearm bones. A vertically sawed section of the tibia shows that the direction of the important bone lamellæ is vertical. In the head of the bone these spread out laterally in a direction to take up the strain of weight-bearing. The direction of the main lamellæ coincides also with the direction in which muscular strain takes effect. Dixon[2] states that the cancellous ends of long bones, in spite of their apparent delicate structure, will resist enormous pressure if the pressure is applied in the normal direction of body weight or muscle strain. (See figure illustrating structure of the calcaneus.)

REGENERATION OF BONE.

How bone grows is an undecided point in pathology. The experimental and clinical observations touching it are of interest here only inasmuch as they cover regeneration after traumatic separation or fracture and its treatment. In the newborn the ends of the long bones entering into joints are round and smooth and separated from each other by cartilage. As age advances, calcium salts are deposited in these cartilaginous areas and cast a shadow in the roentgenogram. The new shadow-casting areas are the epiphyses, the original shaft of the bone the diaphyses, and the remaining clear cartilaginous areas between the two are the epiphyseal lines.

If a sifted resumé of the large amount of recent literature on this subject is to be arrived at, it is necessary to consult many authors

[1] Die Roentgen Strahlen in Dienste der Neurologie, Fürnrohr, Berlin, 1906; editorial, Jour. Am. Med. Assn., November 21, 1914; McCrudden, Tr. XVth International Congress on Hygiene, etc., 1913, vol. xi, Part II, p. 424; and Deutsch. Archiv f. klin. Med., Band cx, Heft 1 und 2, p. 90.

[2] Manual of Human Osteology.

and recall some of the physical facts in the preceding paragraphs. Little has been said about the periosteum previously, because around this tissue has been waged the war concerning growth of bone, callus formation, delayed and non-union, and necrosis. It must be recalled briefly that the periosteum is derived from fetal mesoderm and mesenchyme, which later become connective tissue. The derivations of this connective tissue are closely allied; they are represented by cartilage, ligaments, tendons, fasciæ, and bone, the last of which develops from fibrous tissue as intramembranous bone, or from cartilage as intracartilaginous bone. When the fibrous or cartilaginous tissue becomes bone, cells known as osteoblasts or chondroblasts deposit calcium salts in the fibrous matrix and a bony network results. This network advances in all directions, and later the cells bordering the newly formed osseous tissue condense to make a membrane about it. This is periosteum, and by the time it has become a distinct membrane there is formed beneath it a layer of osteoblasts which proceed to the deposition of the compact bone. The process in cartilage is similar, starting from ossification centres, the perichondrium assuming the function of the periosteum.

Full-developed periosteum is a fibrous membrane closely adhering to the bone circumference except at the cartilaginous ends. The fibers of Sharpey, or fibrous trabeculæ, penetrate at right angles from the periosteum into the compact bone. There are also penetrating bloodvessels branching from the periosteal supply into the cancellous tissue. Histologically, there is no distinct line of separation of the periosteum from the compacta.[1] When an operator peels the periosteum or strips it with instruments, lines of cleavage are found, close study of which reveals different depths of separation. During a growing stage of bone the periosteum contains the osteoblasts in distinct cellular rows surrounded by a fine network of bloodvessels and fibrils. When adult bone condition is attained, these osteoblasts in the periosseous layer disappear for the most part, and only a few cells remain in an inactive state, their number and physiological activity being governed by the functional and irritative demands of the bone. Consequently this fibrous covering of the bone has three layers: the outer tough fibrous tissue which is highly vascularized, a middle elastic layer of varying thickness which is closely adherent to the compact bone, and enclosed between it and the compacta the third or periosseous layer of fibrils and small cells. This third layer in adult bones is very narrow; in growing bones it is thicker and can be divided into two cellular layers, an outer with flattened nuclei, and an inner with oval or round nuclei of younger cells. There is no distinct and constant line of cleavage from the compacta. Removal of the periosteum by sharp strokes of a periosteotome peels off a thinner layer of tissue than painstaking slow reflection of the membrane. This fact may account for the great variations in experimental results of different

[1] Smith, Surg., Gynec. and Obst., No. 5, vol. xv, 550.

observers, because the periosteum must be a varying structure, and its removal would not strike the same level of cells or contain the same proportion of dormant osteoblasts on any two occasions. The age of the bone and its stage of reaction to growth and irritation of metabolic products (alcohol), the amount of blood supply and fibrin present, the mechanical stimuli and destruction, are all variable factors which cause a divergence of experimental results.

Cartilage regenerates largely from the perichondrium, preformed cartilage taking no active part in the new growth.[1] Moore and Corbett[2] say that cutting the nutrient artery prevents formation of periosteal bridge, and as this artery supplies medullary bone, they would conclude that medullary bone is responsible for the subperiosteal bridge.

Gallie and Robertson[3] agree with Macewen.[4]

It must be conceded that the osteogenetic cells of the periosteum, and in a smaller degree the endosteum, take a very active and early part in the regeneration of bone. Later a limited regeneration may follow from the compact or medullary portions. This proliferation is in part at least cartilaginous; it later becomes bony; and there may be a great difference in the relative amount of bone and cartilage formed at different periods, depending on the factors mentioned, namely, age, presence or absence of blood-clot and blood supply, nerve, periosteal and mechanical injury, and, according to some experimenters, the amount of tissue to be regenerated. I believe the last makes little difference, if there is an active healthy proliferative process; it does take a long time to produce solid bone transversely, but the whole shaft of a long bone like the humerus may be regenerated in the longitudinal axis in four weeks if removed subperiosteally. This removal I have performed on human beings, the indication being an acute infection. Growing conditions depend also on the force present, and the specific character of the cells predetermine the character of tissue to be formed. Experimental work demonstrates different results concerning the regeneration of bone, possibly for the reasons given previously. Some results show that there is first an active proliferation of the osteoblasts in the third periosteal layer to form cartilage, which is then rapidly transformed into bone. Regenerated cartilage continues to grow as cartilage, rarely becoming bone. Other results show that the bone is formed outside of the cartilage and

[1] Haas, Surg., Gynec. and Obst., xix, No. 5, also ibid., xvii, 164; Axhausen, Arch. f. klin. Chir., xcix, 1; Davis, Bull. Johns Hopkins Hosp., xxiv, 164; Mallesta, Virchows Arch. f. path. Anat., Berlin, 1906, clxxxiv, 123; K. von Korff, Arch. f. mikr. Anat., 1914, lxxxiv, 263, on histological development of cartilage; Mayer and Wehner, Arch. f. klin. Chir., 1914, ciii, 732; Ortho. Surg., 1914, p. 213; Hawley, ibid., p. 245.

[2] Tr. Western Surg. Assn., 1913.

[3] Canad. Med. Assn. Jour., iv, 33.

[4] Salvetti, Deutsch. Ztschr. f. Chir., cxxviii, 130, Influences of *X*-rays on Callus; Davis, Ann. Surg., lv, 781; Wilensky, Am. Jour. Surg., vol. xxviii, No. 2; Murphy, Surg., Gynec. and Obst., 1913, xvi, 493; Jour. Am. Med. Assn., lviii, 1094; Macewen, Growth of Bone, 1912; McWilliams, Surg., Gynec. and Obst., 1914, p. 159; Jour. Am. Med. Assn., 1914, lxii, 346.

gradually replaces it, using it as a framework. Newly regenerated bone is cancellous; later the osteoblasts in its spaces are arranged in concentric layers like the Haversian systems and are included as bone corpuscles.[1] The periosteum and perichondrium take analogous parts in new tissue formation, and the osteoblasts tend to revert to the chondroblastic type, and when cartilage regenerates its cells tend to revert to a connective-tissue type.

To understand fracture, its course, pathology, and the latest development of treatment, we must know these conditions and also the normal manner of callus formation, the influence of motion and unwise early use, and of the insertion of foreign bodies or autogenous splints. The fate of bone transplanted into soft parts does not interest us here. It is undoubtedly gradually absorbed, because it has absolutely no functional position to fill,[2] and comes to a natural death in accordance with Wolff's law.

Development of bone is of extreme importance, inasmuch as after solution of bone continuity the fragments must be welded and cemented together to reëstablish function in the injured part. This is accomplished by callus.

Callus Formation.—For illustration let us consider a long bone. When it is broken the line of fracture is rarely straight, but is jagged or very irregular, and may include spicules and small loose pieces of osseous tissue between the main fragments. Blood and nerve supply are interfered with, there is a hemorrhagic extravasation, and a clotted mass fills up the space created. The periosteum is torn. Ollier first made clinical note of this fact, but we know now in light of frequent open operations and roentgenographic evidence that this membrane is rarely ruptured completely. It may be stripped up for some distance, or lacerated severely in part of its circumference, but never entirely destroyed. Its quality of elasticity often saves its continuity. Comminuted fragments of underlying compact bone may be completely separated, but remain attached to the untorn periosteum. A good reposition of alignment in such a case, encased in the guiding vaginal periosteum, would lead to a happy cementing in place with a similarly good functional result. If, however, the periosteum is torn from these fragments, they lose blood supply and may necrose in part. This necrosis takes place in the ends of fragments after all fractures, and is of intense importance. A function of exclusion is also assigned to the periosteum; that is, it holds out of the way the intrusion of the omnipresent connective tissue regenerating in the surrounding soft parts, which would interfere with early bone healing.

Displacement, which removes the fracture ends from contact, usually strips up the periosteum and leaves a bridge joining them. This bridge is of importance because, as we have seen, it contains osteoblastic cells capable of regeneration, and a connecting link of tissue potentially able to form bone still persists between fragments.

[1] Gray's Anatomy, Howden edition, p. 59.
[2] Phemister, Surg., Gynec. and Obst., No. 3, xix, 303.

The effusion of blood from bone, periosteum, and muscles at the fracture site is absorbed in a few days, and there is a multiplication of small round cells which cause swelling and edema. A viscid, gelatinous, dark-colored fluid mass then exists around the fracture, which is of practical help in guiding the surgeon to the exact site when he is operating through heavy muscles. The periosteum becomes hyperemic and thickened, and proliferation of the dormant osteoblasts begins. A soft, whitish, bulbous swelling, which is symmetrical in shape, unites the two fractured bone ends, if there is little lateral displacement. This can be palpated in many bones, even in the femur, inside of twelve or fourteen days. Bone regeneration also takes place slowly from the compact and cancellous tissues and beneath or along the periosteal bridges in the effused blood. The blood-clot may be too extensive, and instead of being a help in bone repair may be so large and cause so much obstruction peripherally that it obstructs the general circulation and chokes the lymphatics. This condition would add to the task of bone repair, which is best and quickest performed in the face of accurate approximation and a minimum amount of coagulated blood.

The compact and cancellous surface ends of the fragments become necrotic after fracture on account of trauma and loss of blood supply. For that reason regeneration from these areas is slow, being preceded by an absorption of this necrotic tissue and creeping proliferation out into it of the new islands of bone from the live Haversian canals beyond it. The intervening necrotic tissue is slowly replaced by a process of rarefying osteitis, which removes the bone tissue by first making it spongy and cancellous.

The most important element in fracture repair is the absorption of extravasated blood and the layer of necrotic bone, followed by a reëstablishment of vascular communication between the fragments. This comes from the regenerating and budding vessels in the various bone elements and the erection of new Haversian columns following on the capillary network. Moore and Corbett in their study of the function of the periosteum showed experimentally that cutting of the nutrient artery in rabbits prevented the formation of the periosteal bridge after fracture. Because this artery supplies medullary bone, they are inclined to believe that it, and not periosteum, is responsible for the periosteal bridge.

As previously stated there is a rarefying osteitis which accompanies this process; that is, a withdrawal of calcium not only in the immediate fracture area, but over the body in general. This is probably an adaptive process helping the focal efforts of regeneration through some general stimulative process, and through softening the tissues promoting freer vascular growth, the calcium being replaced later when bony repair has been accomplished. When necrotic tissue is organized by the granulations, the productive efforts of the underlying active osteoblasts send projections into them, and new bone with later calcification into permanent tissue forms. Usually this

new bone plugs the medullary canal completely, and, after the provisional callus, thrown out by the periosseous layer and endosteum, has shrunken and permanent union is established, the medullary cavity is reëstablished by a further absorption of the blocking tissues. Where the displacement is greater, each division of the bone tends to unite with its separated homologous part. If the union is angular, it may be very thick. When there is lateral separation, the callus attempts to pass in the shortest direction between the ends, taking an oblique angle. Laceration of the periosteum with infolding or loss of continuity precludes the formation of this early callus. There is a proliferative reaction in the torn periosteal stumps and in the surrounding muscle or connective-tissue layers, but progress is slower and atypical in form. This is called the provisional callus and is cartilaginous and soft in character. Centres of ossification appear and later the whole mass becomes bony.

Bone fragments of various sizes, when remaining attached to the periosteum and blood supply, are often moulded in with the process of callus formation and are of assistance in filling in gaps and acting as centres of regeneration. If they are deprived of circulation they undoubtedly become necrotic, though some peripheral cells may survive if they are bathed in sufficient serum to maintain life. These dead fragments may cause irritation and delay bone union, or on the other hand, may, like an osseous splint, act as a framework for the new capillary and osseous growth and aid in union.

Davis[1] believes that the provisional callus may not be important in union. He cited a case in which he cut down on the fracture seven weeks after wiring and found nothing on the outside of the bone in the shape of provisional callus, though there was firm bony union. This was probably an exact anatomical reposition with no periosteal laceration.

The effect of Roentgen rays on closed fractures has been studied experimentally on rabbits.[2] A daily exposure of ten minutes, 120 ampères at a distance of 30 cm., promoted a quick production of callus, but a slow deposit of calcium salts. Fränkel[3] applied stimulating doses of the Roentgen rays in cases of old unconsolidated fracture, and his results confirm the value of the chemical rays in starting the regeneration of bone tissue and healing the fracture promptly.

From the cancellous and compact tissue small islands of bone project and the proliferation takes place from the cells of the lamellæ into the fibrils between the fragments. This is pure bone tissue from the start, and a plug forms, which fills the medullary portion of the bone ends and unites them firmly. This is called the definitive callus, which gives a stable and definite union between the fragments. As the provisional callus calcifies and becomes bony, it shrinks until its size approximates that of the normal bone before fracture. The size

[1] Ann. Surg., lv, 781.
[2] Salvetti, Deutsch. Ztschr. f. Chir., cxxviii, 130.
[3] Med. klin., Berlin, xi, No. 8.

is partly governed by the degree of reduction to former alignment. If there is no angular or other displacement, the provisional callus is small and after many months might show no gross evidence of fracture, so closely does it return to the normal contour of the bone. In lateral displacement with oblique lines of deposition the weak side which bears the stress of weight or muscular action fills in firmly and fully, provided the periosteal bridge is present. After function returns this callus becomes permanent, and as the limb is used, there is a natural attempt to restore a good axial line of strength by absorption of the bone on the convex side of the line of greatest functional use and a building up of bone on the concave side. This is particularly noticeable in children, who may thus overcome an angular deformity to an extent which after a few years' time prohibits recognition by comparison with the uninjured limb.

Joint fractures, or those in sites of muscle origin and insertion, where tendon sheaths or fascial layers blend with the periosteum, may cause the formation of callus and permanent bone in the structures mentioned. This is caused by traumatic separation of the periosteum with liberation of cells from the periosseous layer or bone into surroundings favorable for regeneration, or an imbedding of periosteal shreds, membrane-like, about the region of hemorrhage. These areas pass through a cartilaginous stage like ordinary callus, and may later become separated from the neighboring bone and lead to irritative symptoms.[1] Traumatic myositis of similar character is seen in cavalrymen, shoemakers, and others whose occupations furnish the constant irritation of one muscle or part of the body. Some of these cases do not represent real bone formation, but are a calcification of infections or hemorrhagic processes.

Permanent repair process in bone is slow. Can the formation of a satisfactory definitive callus be hurried by early use or motion of the part? Massage, without gross motions which disturb the healing fragment ends, is of use in promoting better blood supply in the surrounding tissues and possibly aids in hurrying the return of function by a vicarious action of exercise. It may also favor an early absorption of the provisional callus.

If early motion is violent enough to break up the capillary network on which the true bone proliferation proceeds, it will delay the process of repair. If more hemorrhage is caused, greater time will be needed to absorb the extravasated blood and the superficial bone layer which becomes necrotic in consequence of its loss of blood supply. As a rule, it is wise to maintain a relative immobilization for a long period in bones which will be subject to great stress and strain of body weight to avoid both these conditions and the clinical bending of soft callus and subsequent loss of function. Around joints where small exuberances of callus may cause great interference with motion, a long rest is indicated. This does not imply a tight, heavy cast of

[1] Fay, Surg., Gynec. and Obst., August, 1914; Frangenheim, Arch. f. klin. Chir., lxxx, 445; Deutsch. med. Wchnschr., xxxix, 497; Orth, Berl. klin. Wchnschr., xliii, 430.

plaster, but it does mean quiet, rest without rough manipulation or handling, until continuity is firmly established. Helpful massage can be given without endangering prompt union.

Sluggish union, or delayed union from unknown causes, is often stimulated by use and mechanical irritation of the fragment ends. This is provided through the application of strains in the normal axis and direction of the limb, especially of the leg, by the operator encasing it in plaster or supporting it in normal position by means of a splint and then encouraging the patient to bear a little weight on it. This gives a slight irritation at the bone ends which stimulates regeneration. Various other means are used to attain the same result. (See Pathology and Ununited Fracture.)

What is the effect of implantation of foreign bodies like nails, screws, or steel plates on callus formation and bone union? This point is dealt with in the chapter on Operative Treatment, but some general observations may be made. Nails and screws have little or no effect on callus formation and union. Their presence in long bones occupies such a small area that their action, if untoward, is limited and of no value. Clinically I have never seen any untoward effect from them, assuming of course that there is asepsis and immobilization and a fair reposition of fragments. Plates fixed with screws have given various results in different hands. Some surgeons believe there is not the slightest doubt that such plates cause a delay in union and frequently lead to non-union. If we consider that the plate occupies but a small area of the total bone circumference, it does not seem possible that it can interfere much with blood supply and bone growth. The various experiments to determine the effects of plates or internal splints of foreign material have led to different conclusions. Macewen in his silver-ring experiment believed that he obtained bony growth beneath the ring with periosteum stripped off, and for that reason assigns the role of limiting membrane to the periosteum. Mayer and Wilmer, who repeated Macewen's experiments, using steel or glass caps, obtained no growth beneath them, and Hey-Grooves, who attempted to determine whether rapidity and firmness of bone repair were better promoted by intramedullary pegs or external plates and screws, failed to comply with technique and after treatment used on human beings. His results showed that without additional external fixation, the screw holes of attached plates became loose and sepsis was likely to follow. This would naturally follow when the plate was made to take up the strain of the whole bone shaft in use permitted before there was any bone union. The stress on the screws caused pressure and absorption of the bone in which they were embedded. By using long plates held firmly by cotter pins which pierced the bones and were bound down tightly, he obtained better results, with little external callus, and examination of specimens showed an aseptic necrosis of the bone up to the level of the first pin on either side. He thought that the bent pins kept the periosteal blood supply away from the broken ends. It is my observation that best results follow plates

applied firmly outside of the periosteum, to hold fragments in place until strong union has followed. If they are not so placed they may hinder repair through allowing movement and mechanical irritation, bone absorption, fluid collection, with sinus formation and sepsis following. The muscular tension acts on healing tissue, it is not taken up by the inefficient fixation splint, and union is delayed. Bone does not act like wood; being a living tissue subject to biological reaction it will not maintain for a long time any screw thread which has been inserted into its tissue, provided the surface of this thread is subjected to continuous strain. The thread cuts its way through until tension is relieved. Healing takes place only when there is a condition of equilibrium, and the conclusion must follow that *next to asepsis, mechanical efficiency of fixation is of greatest importance.*

Outside metal collars of any metal give good fixation when placed between bone and periosteum, but the collar interferes with external callus, and although a firm internal callus develops, the method has no practical value. If applied loosely enough to permit bone growth beneath, it would also allow movement and inhibit union. Hey-Grooves says: "When the periosteum is excluded, union by callus still occurs, but the field of repair, being shut off from the vascular supply of the periosteum, produces its callus slowly and in small quantities." In comminuted fractures all fragments should be preserved, as they become centres of bone proliferation. Consequently, if open operation is done, the operator should avoid interfering with the blood supply of these small fragments by manipulation. Near joints a different problem arises: no great amount of callus and no rigidity is desired; hence it is advisable to remove small fragments which cannot be very accurately replaced, and to avoid motion for a longer time. This procedure lessens mechanical irritation and excessive or function-restricting callus.

BONE TRANSPLANTATION—FATE OF TRANSPLANTS.

In reality this work is interested in bone transplantation only insofar as it concerns the treatment of recent or ununited fractures by inlay grafts or intramedullary splints. There are several different views held by experimenters and clinicians, and as the controversy still rages and no final decision has been reached at this time, it is evident that it lies without the scope of this work to make authoritative decision. In a previous statement it has been said that bone regenerates from the osteoblasts in the subperiosteal layer, from the endosteum and the cancellous tissue. When bone is removed and reimplanted into a bony bed of the same animal, when there is autogenous grafting, with asepsis, a bone union results. What is the fate of the transplanted bone? Is it absorbed completely or partly; does it become necrotic and offer its structure as a framework for regenerating bone entering the area, or does it continue to live and enter into the final bone union as one of the essential elements? Various

authorities, with ideas fixed by clinical or experimental conclusion, or a combination of both, have different ideas. For the purpose of clinical results and a successful bony union in fresh or ununited fractures, it seems best to use transplants with periosteum attached. Macewen and McWilliams hold that the transplant lives in part at least. Murphy believes that the transplant dies and offers a framework to regenerating bone which creeps along it, Barth's original idea. Clinically bone pegs and transplants do disappear after a time, and Mayer and Welmer hold that this fact refutes Macewen's idea.

Probably Lexer's statement[1] that the function of the graft lies in the fact that it replaces missing tissue and enables the body to build up new bone is satisfactory from a clinical standpoint. Autoplasty is the method of choice; heteroplasty of bone boiled or in other ways sterilized has been done successfully, but it undoubtedly takes much longer to secure a bony union, the foreign body being absorbed as the new bone is laid down (Petroff). Presumably the osteoblastic cells of the endosteum and periosteum of transplants retain their vitality because they are exposed to the serum of the new bed in which they are placed. Most of the cells deeper in must undergo necrosis, because they are deprived of nourishment. Under the necessary condition of asepsis and blood supply these two parts of the bone which retain life proliferate and cause a cementing of the graft to its new home. Some of these cells also grow into the Haversian canals of the deeper necrotic graft, absorb it, and lay down new bone. Clinically most operators use bone grafts with periosteum—it is the wisest course. If it is removed, experimental work seems to prove that the cementing callus and the osteogenetic substitution of the graft are very slow. The osteoblastic cells of the periosteum are lacking in part, and regeneration comes from the endosteum and cancellous bone. There is also probably an ingrowth of the transplant by the generating cells of its new bed, when it is itself lacking in osteogenetic material. The endosteum and periosteum may be destroyed by infection or lack of nutrition, but most of the substitution seems to come from its own cells.

REFERENCES.

Davis and Hunnicutt. Bull. Johns Hopkins Hosp., xxvi, No. 289.
Gallie and Robertson. Canad. Med. Assn. Jour., iv, 33.
Lexer. Loc. cit.
Hosmer. Northwest. Med., 1913, v, 329.
Axhausen. Arch. f. klin. Chir., 1908, Band lxxx, viii; Deutsch. Ztschr. f. Chir., 1907. Band xci; Arch. f. klin. Chir., 1911, Band xciv.
Barth. Ziegler's Beitr. z. pathol. Anatom., 1896, Band xvii; Arch. f. klin. Chir., 1893, xlvi, 409.
Phemister. Surg., Gynec. and Obst., xviii, No. 4; ibid., xix, No. 3.
Murphy. Jour. Am. Med. Assn., April 7, 1912; Surg., Gynec. and Obst., xvi, 493.
Turnbull. Arch. Patholog. Inst. of London Hosp., 1908, ii.
Mayer and Wehner. Loc cit., and Arch. f. klin. Chir., 1914, ciii, 732.
Gallie. Am. Jour. Orthop. Surg., September, 1914, xii, No. 2.
Putti. Arch. di ortopedia, anno xxx, Fas. ii, 1913; Soc. Med. Chir. de Bologna, 2 Mai, 1913.

[1] Ann. Surg., lx, 166.

Bond. Brit. Jour. Surg., April, 1914.
Albee. Am. Jour. Surg., 1914, xxvii, 20; ibid., March, 1915.
Lewis. Surg., Gynec. and Obst., May, 1914, p. 572.
Oechsner. Surg., Gynec. and Obst., 1914, xix, No. 4.
Cohn and Mann. Southern Med. Jour., 1914, vii, 214.
Morrison. Brit. Jour. Surg., No. 3, i, 376.
Macewen. Ann. Surg., 1909, No. 6, l, 959.
Ganglophe and Bertein. Lyon Chir., xi, No. 6.
McWilliams. Jour. Am. Med. Assn., 1914, lxii, 346; Surg., Gynec. and Obst., February, 1914, p. 159; Ann. Surg., April, 1914.

BONE REPAIR IN OPEN FRACTURE.

The process of repair and healing in open fracture may not vary from that of simple fracture. It is a clinical delight to obtain an open fracture with a small external opening which heals as quickly and happily as if it were a closed affair. This result is largely caused by the type of fracture, the open character being caused by force within the limb, and the factors which govern the changes in repair of open fracture.

The two factors are, first, the greater local violence and destruction of tissue, and second, infection. Most open fractures have been subject to greater direct violence with crushing and mangling of the soft parts. Muscles, fascia, periosteum, and bone have been severely injured and their blood supply interfered with beyond the usual damage of closed fracture. Even with infection and suppuration absent, it is easily understood that repair and ultimate bony union will be longer in appearance if conditions of open fracture are present. When the fracture is opened from within, this violence is not commonly present, and sepsis is not so frequent. It is also true that a small hole through skin and soft parts acts as a drain, and the early blood extravasation, instead of demanding absorption within the tissues, is poured out into dressings, and the bone repair follows more quickly. Tissue reaction, absorption of traumatized soft and bony parts, reëstablishment of circulation, and the subsequent bone regeneration will demand a longer period of time than in cases of simpler closed fracture.

Infection, the second factor of importance, also delays the process and modifies it. I believe that trauma and interrupted blood supply have much more to do with a delayed callus formation by the periosteum than infection has. This opinion is based on experience with open fractures and the resection of bone shafts in osteomyelitis of different degrees. In the presence of infected bone the periosteum will go on forming new bone until an infected shaft will approximate twice its normal size, and if this necrotic bone is peeled out of its covering the periosteum will be found relatively healthy and active. Its vigorous blood supply accounts for this condition. Another striking example of bone healing and regeneration in the face of sepsis is found in the ribs after resection with drainage for empyema of the chest. When bone becomes infected, its lymphatics plugged and its blood supply interfered with, necrosis surely follows, but periosteum is not

affected so extensively. Consequently repair is slower in infected open fractures, not so much because the periosteum is destroyed by the infection, as because it has suffered greater destruction from loss of nutritive supply. Infection on top of this may cause the bone covering to fall an easy prey in company with the bone itself, but, as a rule, the periosteum retains its vigor and life more tenaciously than the bone, and the longer time required for union in infected fracture must be accounted for by the bone reaction.

Small fragments live and become the centre of new bone growth, if their blood supply is sufficient and infection does not overcome them. It is better to leave them lying in the wound, although they may appear unprotected. Bony granulations gradually cover the site of fracture, and fragments deprived of vascular connection, although really foreign bodies, are well tolerated by bone, very much as implanted autogenous bone is. If the field is sterile, no subsequent trouble is looked for; if infection appears, these small pieces will probably be cast out or need to be removed.

Bone extruded through an opening in the flesh and deprived of usual surroundings may necrose, and a line of demarcation may mark the level of living and dead tissue, as in other structures of the body. It is also a fact that the thin external surface or shell of this bone may necrose alone and leave viable tissue beneath. Deeply planted infection in osseous tissue thrives largely because of the physical structure of the bone and its limited blood supply. There is not much chance for the phenomena of protective inflammation to build up quickly a resisting wall of leukocytic infiltration. The rigidity and hard structure forbid this. Reaction to deep infection is slow; necrosis of the areas in which a circulatory stasis develops is the outcome. Consequently infection introduced by screws of Lane plates or other foreign bodies penetrating the compact layer, finds little resistance and causes a prolonged suppuration and necrosis. When a bone shaft is extruded in open fracture and its covering is retained, infection is warded off by the periosteum, and this bone may be open to the air for a long period of time and retain vitality and show no infection which leads to necrosis and suppuration. It is less liable to be subject to a suppurative process than bared bone lying in soft tissues, because it is dried and not constantly surrounded by the tissue fluid and serum which do not drain away completely. I saw an example of this type of open fracture recently with Dr. Kelly at Mercy Hospital. A woman had received a severe skull fracture and an open fracture of the left arm just above the elbow. She was in very bad condition, and although a decompression of the skull was performed, the case was classed as almost hopeless. To avoid additional shock, the arm, with several inches of humerus protruding through the skin, was dressed and no effort at reduction was made. After being in a critical condition for days, she eventually made a recovery. The humerus has received no attention looking toward reduction. Three months later when I saw her, the soft parts above the elbow had

healed, and there were four inches of the shaft of the humerus protruding, covered with dirty yellow and red granulations, but not suppurating. It was quite dry. Operation was performed, and the lower fragment, which consisted of the humeral condyles, was laid bare and freshened. The arm had contracted somewhat on account of lack of bone support, but instead of cutting off the protruding portion of the shaft of the humerus, the granulating fungus-like covering was peeled off, and bone which had blood supply and appeared viable was found beneath. By manipulation and nicking of the muscles, a reduction was accomplished, the freshened bone ends were fastened with silver wire, and a recovery without suppuration followed. This bone had been protected by periosteum and the dry dressings, and no infection had occurred deep in its tissue.

Callus repair in open fractures generally takes longer than in closed fracture. There has been more injured tissue to absorb, the bone reaction has been more vigorous, and the necessity of dressings or drains and manipulation has caused more motion at the site of fracture. Irregularities of the callus and adherence of the soft parts to it are the usual sequels. If infection is a part of the recovery, the tenderness of osteomyelitis is added, and after recovery the fracture is tender, enlarged, and troublesome. Deeply buried fragments or infection may prolong irritation for many months. Absorption and final changes long after union leave an irregular callus, some areas very hard and eburnated, others pitted. Bony trabeculæ may extend along fascial planes or tendon insertions, as mentioned previously.

Fractures which involve the ends of the long bones, where the compact layer is thin and cancellous tissue composes the greatest bulk of the surface, heal rapidly without much preliminary absorption. Regeneration is derived from the spongy bone, the periosteum furnishing less callus and usually suffering less injury or stripping, because it is held by attachment of ligaments and tendons. In malleolar fractures at the ankle it is an ordinary finding on the performance of open operation for nailing, that the bone tip is broken completely off and the ligaments and periosteum are torn off quite exactly at the line of fracture. The periosteum does not tend to strip up. These fractures are replaced exactly and held in position by nails. After six weeks, when splints are removed, the malleoli are in normal position, the patient can *at once* move the ankle quite freely, but in spite of the careful reposition the ankle seems swollen and thick. This is not all callus, but is partly, I believe, the infiltration in the soft parts and ligaments which has not subsided. It in no way interferes with motion and function. I have never yet had an opportunity to dissect an ankle after nailing and healing, nor have I ever taken out but one nail, so that definite pathological knowledge of this swelling is not possessed by me.

When the line of fracture enters the joint surface, the articular opening heals by granulations from the synovial membrane and the cancellous bone, as there is no periosteum there. Rarely the callus

from the spongy bone is exuberant and extends out into the joint. As previously stated the joint cartilage does not regenerate much, and the fracture is fixed by the extra-articular callus arising from the periosteum. The line of separation often follows the epiphyseal line or cartilage when they are still present. This point is discussed under Wrist Fractures, many of which, in children, are of this character. If they are replaced, union and growth seem to be normal in every respect. There are a few cases on record in which the cartilaginous area has been overcome by the osseous reaction, becoming calcified, and growth has ceased.

Excessive callus usually is an unwelcome complication in any fracture. Near joints this condition always interferes with motion and function, and it should be guarded against as much as lies in the power of the surgeon by his obtaining accurate apposition of the fragments and avoiding early movement, which may cause bony proliferation. A very small amount of callus which fills a normal depression in bone, like the olecranon fossa, or which protrudes but slightly in the way of normal joint action, often causes much disability. Likewise when two broken bones lie close together callus may unite all four fractured ends or spread out between them *via* the interosseous ligament and stripped periosteum, leading to great restriction of motion. (See Fracture of Forearm Bones.) As a rule, however, the calluses, even when exuberant and approaching each other, form a smooth surface when in contact which permits movement of rotation. Clinically this is of little importance in the leg, ribs, or any other part of the body except the forearm.

The opposite of excessive callus is observed in those cases of non-union in which bone rarefication has taken place and granulations have proceeded, but calcification and osseous formation have not followed. Use and motion may cause formation of a false joint at the site. (See Pathology.) The condition is found in the shafts of long bones, in the neck of the femur and in the patella, olecranon, head of the radius or humeral condyle, or other portions broken off near an articulation. The underlying cause is lack of blood supply to both bone and periosteum, or destruction of periosteum and its generating osteoblasts.

COURSE OF FRACTURE.

The clinical course varies with the patient's general condition, age, the complications which arise, and the character of the reposition or other treatment. There is a change in behavior according to general constitutional diseases or conditions which seem to depend, as suggested, on the calcium equilibrium. Lane believes that alcoholism is one of the greatest disturbing factors of ordinary bone repair. Syphilis, tuberculosis, rickets, and other constitutional diseases like diabetes, acromegaly, or constitutional conditions of obscure origin

like arteriosclerosis, myocarditis, or even varicose veins, have an influence as described in the chapter on Pathology.

The course may be divided into local and general effects. After the first few hours of nervous upset, or local pain, an individual who has suffered fracture is usually comfortable, unless he is disturbed by tight bandages and splints or useless manipulation. These lead to muscle spasm and twitchings and aching discomfort. The injured member is shortened and enlarged on account of edema and bone displacement. If the limb and part are placed in a comfortable position the first reaction slowly subsides; swelling and edema disappear after reaching a maximum on the third to fifth day. Ecchymoses and blebs become noticeable later and may last for weeks. The greatest discomfort in the normal course is not pain but the irksome confinement, the wearing of splints, disability, and change of daily habits. Fat embolism is manifested within twenty-four hours, pulmonary embolism from a dislodged clot usually occurs after several days. Pneumonia caused by the trauma, exposure, or recumbent position comes on within a few days, as do also the sequelæ of alcoholism. Delirium tremens may take onset within twenty-four hours after fracture, if the patient is a pronounced alcoholic and the supply of alcohol is withheld. It also comes on late in less pronounced habitués—or follows an anesthesia administered for reduction and dressing. Very rarely after an early alcoholic delirium and recovery the patient will relapse into a second attack within a week. The aged frequently develop an asthenia or hypostatic pulmonary congestion, and death from exhaustion ensues.

A fever is often found clinically, caused by an aseptic absorption of the extravasated material at the fracture site. From this cause alone the temperature rarely goes above 100° F. The kidneys may be influenced by this absorption, and the urine may show albumin and casts for a day or two. Fat distributed by absorption and fat embolism or lipemia is also excreted from the kidneys. An increase in the white blood cells is also a constant clinical finding, affecting the polymorphonuclear cells. The eosinophiles are first decreased in proportion and later increase in healthful reaction. The blood changes all become normal after two weeks.

Eight or ten days after injury, if rest has been afforded to the limb and ice has been applied, the swelling and edema disappear, and the ecchymoses with tints from black to light yellow are prominent. The external callus can be felt through the superficial tissues as an oval, firm mass. This becomes harder and at first may increase slightly in size; later it shrinks, the false point of motion at the seat of fracture is no longer demonstrable, and union exists. The diminution in size of the callus takes a varying time, depending on the individual and the type of fracture. Some enlargement is often permanent and can be felt after many years. This repair and absorption of callus is more vigorous in children and in cases where there are no complications. Each bone has its own period of repair, which will be indicated in sub-

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sequent chapters. Long bones require a longer time to heal than small bones. Shaft fractures of long bones with a thick compacta require a longer time than fractures through the cancellous portions and poor alignment, comminutions, and other unusual pathology requires greater time for union. A phalanx may unite in two weeks; the neck of the femur might not present solid union after six months or a year.

Many fractures which are well reduced and splinted are mishandled in after treatment because sufficient rest, time, and splinting are not permitted to allow the callus to become calcified and fit for weight bearing. These points are discussed under the different bones, especially in femoral, forearm, and ankle fractures, in which too early use may lead to a deformity as bad and as disabling as the original displacement. The mere fact that callus has formed between bone ends does not terminate the care of the fracture, any more than the healing of a laparotomy wound and removal of the stitches indicate that the patient is again restored to normal. The bone wound or scar will stretch much more than a union in soft parts because when function is started it is subject to greater stress and strain. The limb involved must also undergo some nutritional changes on account of rest and muscle inactivity. After splints and casts are removed permanently, even when massage has been used in the course of repair, there is considerable swelling and edema from circulatory and lymphatic changes. Use soon overcomes most of these conditions, but the disability after fracture, the stiffness and soreness in neighboring joints, and the little aches and pains are sources of discomfort in many patients. Perhaps this is particularly so in a neurasthenic class. Artisans and laborers generally forget the trouble in the struggle for existence.

CHAPTER II.

ETIOLOGY AND MECHANISM OF FRACTURE.

The causes of fracture are (1) predisposing causes and (2) exciting or immediate causes. The predisposing causes are:

(*a*) Functional or physiological.

(*b*) External influences, occupation, season and exposure.

(*c*) Pathological conditions.

(*d*) Intra-uterine and obstetrical.

Fracture may be defined as a solution of the continuity of bone. Predisposing causes for this solution are found in:

(*a*) **Functional or Physiological Causes.**—These lie in the fact that bones act as a protection to body viscera and soft parts, as the skull protects the brain and the ribs, the chest, and that as the rigid framework of the body, the bones must finally take up the stresses and strain, transmitted by the muscles and ligaments, which come in ordinary exposure and work of life. As we have seen in the chapter on Bone, the structure is adapted to these necessities, but when a limit of elasticity is passed, the bone continuity suffers. Physiological changes incident to constitutional disturbances, or physiological periods of life, also predispose to fracture. The calcium equilibrium undoubtedly is a factor of great importance. The atrophy of the trabeculæ of the cancellous tissue, the increased calcification of the compact layer, and the increase of fatty medullary substance in the aged, are also factors of interest. These may reach such a degree that they border on the pathological. The bones of certain individuals who are otherwise normal seem predisposed to fracture by an hereditary influence or some personal idiosyncracy. Members of families for several generations may show a tendency to easy and frequent fracture. Gurlt's *Handbuch* cites one family as disposed through four generations. Individual tendency in this direction is often met with, and there are scattering reports in the literature—the number of breaks in one individual amounting sometimes to more than a score. I have recently cared for a man who gives the following history of fracture in the last thirty-six years. He first sustained a fracture of both bones of the leg. Two months later he fell on some ice and fractured the femur, and ten years later he sustained a bimalleolar fracture, all in the same leg. After an interval of several years he had a Colles fracture of the left arm and finally had a fracture of the anatomical neck of the left humerus. The Roentgen picture leaves no doubt that there is some calcium deficiency in his bones, but there is no variation in size or any other evidence of pathology in the skeleton to account for his peculiar liability.

(*b*) **External Influences.**—Other predisposing causes arise from outside influences incident to occupation, sex, age, season, and exposures of life. Occupation and sex are closely intermingled, because males as a rule perform the harder labors and are occupied in more dangerous work. In a consecutive series of 10,702 fractures studied at the Cook County Hospital I found that there were 7954 closed fractures and 399 open fractures in males and 1154 closed and 27 open in females. The remainder were in children. An investigation of occupation in this same series shows that 2662 were laborers, who performed relatively rough work of all classes which furnished exposure to trauma. Teamsters came next in the numerical list, furnishing 737 instances of fracture. Naturally it is impossible to decide which occupation is the more hazardous—figures could not tell us that unless an exact number of men in the different trades were working in one vicinity under the same conditions, and observations made on them for a period of years. Painters pursue a hazardous occupation, and though it is impossible to state the relative number of them at work in the community contributing to this hospital, I have selected them as a means of comparison. Of 10,702 fractures, 277 were in painters. Carpenters furnished about $\frac{2}{3}$ as many cases as painters, firemen $\frac{1}{3}$ as many, mechanics or foundry men about $\frac{1}{3}$ as many, and trainmen about $\frac{1}{2}$ as many. In the female sex housewives furnished 647 cases, cooks and domestics about $\frac{1}{4}$ as many, and waitresses a very small proportion. Seasonal variation is not so important as former writers thought. The modern city with surface transportation, a large amount of summer building and extension, and a restriction of these activities in the winter, counterbalances any great increase in fractures caused by falls on ice or weather conditions or the doubtful influence of muscles stiffened by cold and exposure.

My analysis of eight years' admissions to the hospital on account of fracture showed that there were 2688 in the summer, 2675 in the spring, 2624 in the winter and 2560 in the autumn.

(*c*) **Pathological Fractures.**—Pathological conditions which represent diseases of the bones themselves, or metastases and extensions of disease from other parts of the body, include the third class of elements predisposing to solution of continuity. These injuries have also been called spontaneous fractures, because they seemed to be caused without any violence, the fracture occurring in an ordinary act like walking, stepping, or swinging an arm. The bone is weakened by the pathological condition until it is no longer able to bear even mild stresses, and slight exertion or movement is all that is needed to produce fracture. Pain is often absent. The patient walking feels a leg or thigh give way and falls down helpless, or in turning or being moved in bed feels something snap and finds a limb useless.

In the chapter on Bone attention is directed to the importance of the constant growth and changes in the bone after it is laid down and to its metabolism which corresponds to that of other tissues. The calcium equilibrium is disturbed in many conditions, such as

osteoporosis, chronic infection of syphilitic or coccic origin, osteomalacia, rickets, dwarfism, etc., the calcium salts either being diverted to other tissues or perverted into bony deformities. A pregnant woman draws on her store of calcium to supply the fetal bones, and if a balance is not restored after the child's birth a condition of osteomalacia may result. Tumors, primary or metastatic in bone, fractures, arteriosclerosis, a lessened bone-building power of old age, and other conditions cause a similar calcium depreciation. McCrudden in his work on infantilism at the Rockefeller Institute[1] made a study of the metabolism of proteins, carbohydrates, fats and inorganic salts. He believes that clinical cases of defective growth may be divided into two classes: one with tender and undeveloped bones and disturbance of calcium metabolism, the other, without calcium deficiency and with normally thick resisting bones.

As nearly as can be decided from the literature, fragilitas ossium,[2] osteogenesis imperfecta, and idiopathic osteopsàthyrosis,[3] are all the same condition. There is a congenital lack of power to form bone, the laminæ are imperfectly calcified or are lacking altogether, there is an aplasia of both compacta and spongy tissue, so that fracture easily occurs. This is always in the diaphysis, according to Maier. Achondroplasia usually affects the cartilage and not the bone, osteomalacia concerns calcium changes in grown bones, and rickets concerns the whole bone, including the epiphyses. Repeated fractures of infant bones are really found in osteogenesis imperfecta alone, and Bookman[4] and Bamberg and Huldschinsky[5] agree that there is a negative calcium balance. Phosphorized cod-liver oil probably increases the calcium retention. Many fractures arising from this condition occur before birth, and many fetuses are born dead. The bone fragility is noticed from the ninth month to the second year, when the child is learning to walk, or from the sixth to the fourteenth year upon physical exertion. Shortening and deformity in the bones are caused by the fracture displacement. The fractures of early childhood are most often transverse and heal with much callus, while those of the late form are also oblique and tend to heal very slowly with poor callus formation. Blue color in the scleræ is considered a pathognomonic sign.[6]

Other interesting isolated cases are recorded by Remy[7] and Plisson.[8] The former's patient was twenty-six months old. He sustained in all six fractures within a period of a year while walking across the floor. These were all rapidly and completely repaired. Plisson's case had

[1] Deutsch. Arch. f. klin. Med., Band cx, Heft 1 u. 2, p. 90.
[2] Ostheimer, Jour. Am. Med. Assn., lxiii, No. 23, p. 1997.
[3] Frangenheim, Ergeb. d. Chir. u. Orthop., iv, 134; Axhausen, Deutsch. Ztschr. f. Chir., xcii, 42; Lobstein, Traité d'anatomie pathologique, 1833, ii, 204.
[4] Am. Jour. of Dis. of Children, 1914, vii, No. 6, p. 436.
[5] Jahrb. f. Kinderh., 1913, lxxviii, 1214.
[6] Burrows, Brit. Med. Jour., 1911, ii, 16; Cockayne, Ophthalmoscope, 1914, xii, 271; Conton, Bost. Med. and Surg. Jour., 1913, clxix, 16.
[7] The Medical Council, xix, No. 1, p. 15.
[8] Clinique, 1913, p. 132.

eighteen spontaneous fractures in nineteen years and was then put under treatment by adrenalin, since when no fractures have occurred.

Rickets with softening and bending of the bone also furnishes a pathological basis for fracture, largely by a change in the calcium content, which causes loss of firmness and rigidity. Old dislocations, particularly those of the shoulder, may lead to fracture of the bone from slight trauma or efforts at reduction. The bone probably undergoes an atrophy of disuse, and less force is needed to cause fractures than under normal circumstances. The atrophy is really a change in calcium content, and though more force is applied than the operator intends there is also a weakening of the bone. I have fractured the humerus in a dislocation of three months' standing while attempting reduction and talking of this very point, the necessity of guarding the amount of force expended.

The nervous system also has on bone an influence which predisposes to fracture. Neurotrophic influences in insanities, in paralyses and particularly in tabes must be considered. In the Cook County Hospital we have from 12 to 15 cases each year of pathological fracture or fracture-dislocation of the long bones in tabetics. These are usually near the joints, they are accompanied by much bone change of a rarefying or hypertrophic character of typical Charcot joints, and they are also quite painless. Some patients present three to five fractures at the same time. Many of these heal, and a deformed but functionating limb results. Rarely a fracture of this character is the first intimation of a parasyphilitic condition, well-developed tabes appearing in a few months or a year after a fracture from trivial cause.

Syphilis itself rarely leads to pathological fracture. The bone changes are almost always hypertrophic in character, and shafts are greatly thickened. Tuberculosis sometimes, in an isolated area, leads to pathological fracture. Parker[1] has reported a case due to tuberculosis in the lower end of the femur which healed promptly. Pathological fractures are also caused by multiple myelomata, or are found in cases of myelopathic albuminosuria, as described by Bence-Jones in 1847.[2]

Benign bone cysts, ostitis fibrosa or fibrocystic disease of bones, cause pathological fracture. Many cases are now on record in the literature, the spontaneous fracture, or one induced by operation, often curing the condition.[3] Cysts caused by the echinococcus, cysticerci or actinomycosis or chronic osteomyelitis of bacterial origin[4] may result in fracture. The diseased portion of the bone is not always the weakest, however, as shown in a case with a spiral fracture of the normal part of the shaft of the humerus, with a bone cyst just above the site.

[1] Jour. Am. Med. Assn., September 19, 1914.

[2] Groves, Ann. Surg., lvii, 163.

[3] Lewis, South. Calif. Pract., April, 1910; Elmslie, Brit. Jour. Surg., ii, No. 5, p. 67; Stierlin, Deutsch. Ztschr. f. Chir., June, 1914; Low, Lancet, January 31, 1914.

[4] Landois, Med. Klin., Berlin, 1914, x, 269.

Malignant disease, particularly sarcoma and carcinoma, is the most common cause of pathologic fracture. Pathologically it is known that certain carcinomata, especially of the breast, prostate, adrenals and kidneys, and malignant goitre, have a predilection to establish metastases in bone-marrow.[1] The erosion and weakness in structure which they cause and which result in spontaneous fracture may be the first clinical evidence of the disease. There is no primary carcinoma of bone but primary sarcomata are common. Diffuse carcinomatosis of bone metastatic from other tissues with multiple fractures, is illustrated in Figs. 1 and 2. The humerus and femur are favorite

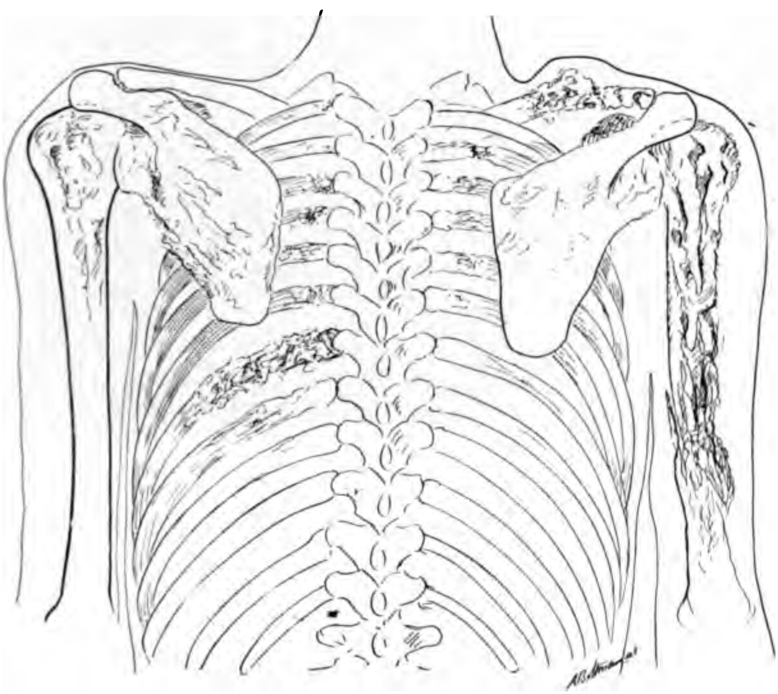

FIG. 1.—Extensive carcinomatous involvement of the bones. Right clavicle and humerus are the seats of pathological fracture.

sites of involvement, and there are clinically few symptoms of pain or bone disease before the spontaneous rupture. Hawley[2] quotes Limacher, who found metastases in bone from carcinoma of the breast in 7 cases, and Lenzinger, who found the bone metastases of carcinoma of the thyroid comprised 37 per cent. of cases. Almost invariably more than one bone is involved, a condition differing from some forms of sarcoma which have a solitary metastasis. The vertebræ, humerus, femur, ilium, ribs, sternum, skull and bones of the extremities are usual sites,

[1] von Recklinghausen, Festsch. z. Virchow 71, Geburtstag, Berlin, 1891.
[2] Ann. Surg., li, 636.

the metastatic invasion being of miliary type from the blood, affecting the long bones in the marrow of their expanded extremities and the vertebræ in their bodies. A slow restricted growth of the newly deposited tumors results, osteoporosis extending from within outward proceeds, and there is a compensatory periostitis which forms new bone. Compared to the number of these metastatic growths, the complicating spontaneous fractures are quite few. Weakness and

FIG. 2.—Lower extremity of the preceding figure. Carcinomatous invasion of the bones, pathological fracture of the femur.

pain or deep tenderness over the bones are symptoms, but tumors gross enough to attract attention are rare (Fig. 3).

In the discussion of Rodman's paper on Cancer of the Breast read before the Clinical Congress of Surgeons at London, July 31, 1914, Handley[1] brought out some interesting figures in support of the permeation theory of the spread of carcinoma *via* the lymphatics.

[1] Surg. Gynec. and Obst., 1915, p. 72.

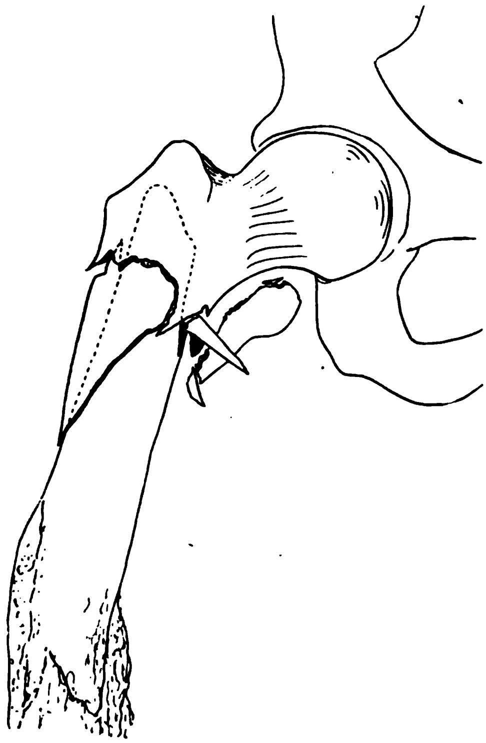

FIG. 3.—Carcinomatous invasion of the femur with a comminuted fracture through an apparently healthy portion of the bone above.

SPONTANEOUS FRACTURE IN 329 CASES OF MAMMARY CANCER AT THE MIDDLESEX HOSPITAL, 1872 TO 1901.

	Bone.	No. of cases.	Percentage of total.
Bones lying wholly or partially within the area liable to subcutaneous nodules.	Sternum	30	9.0
	Ribs	28	8.0
	Clavicle	5	1.5
	Spine	12	3.6
	Cranial bones	9	2.7
	Scapula[1]	1	0.3
	Femur	14	4.2
	Os innominatum[2]	0	0.0
	Humerus	9	2.7
Bones lying beyond the area liable to subcutaneous nodules.	Radius	0	0.0
	Ulna	0	0.0
	Tibia	1	0.3
	Fibula	0	0.0
	Patella	1	0.3
	Bones of hand	1	0.3
	Bones of foot	0	0.0

[1] This bone, owing to its shape, is not much liable to spontaneous fracture, and rarely comes under observation at an autopsy.

[2] Knee ankylosed, femur affected in its whole length, with extension of growth to patella and head of tibia.

He believes that breast carcinoma always spreads in a centrifugal manner through the lymphatics, the tract being obscured as the disease so permeates, and the whole condition can be likened to a gigantic ringworm. He offered the accompanying table in support of his study, and states that the arms below the elbow, and legs below the knees, are not the seats of metastatic deposits, although we would expect to find the evidence of embolism in the extremities if the distribution occurred via the blood stream.

Sarcoma is often primary in bone and leads to spontaneous fracture. Some forms of sarcoma have a solitary metastasis in bones, especially the hypernephromas. Scudder[1] reported a case of amputation of the arm for supposed sarcoma of the upper end of the humerus. Examina-

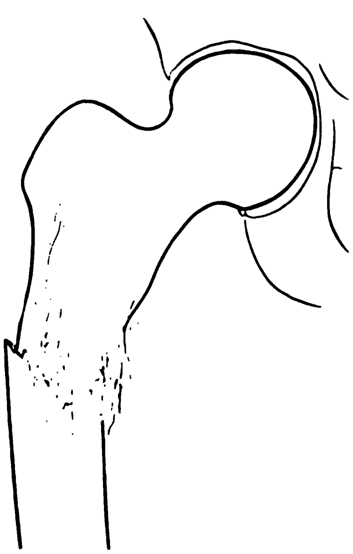

Fig. 4.—Sarcoma of the femur and pathological fracture.

Fig. 5.—Sarcoma of the humerus with false motion at the site of the tumor.

tion proved this was a metastatic hypernephroma. Nephrectomy was urged but was refused, and after death five years later no other metastases were found in the body. Albrecht[2] also says there are solitary metastases in hypernephroma. Primary bone sarcomata do not metastasize early and are difficult to differentiate from bone cysts. Removal of the part of the bone affected may be sufficient treatment. Whether sarcoma follows the trauma of fracture or not is a disputed point. I have removed the mandible for sarcoma of the jaw in a case which gave a history of fracture a year before at the same site, and the size of the tumor and lack of metastases did not seem to

[1] Ann. Surg., lii, 533.
[2] Arch. f. klin. Chir., lxxvii, 1073.

indicate that the tumor had been in existence before the fracture. Coley has reported a case and Griffin[1] reported sarcoma following the plating of a femur for fracture. Murphy states that fracture is never followed by sarcoma—it is injuries of less degree which may cause the onset of malignancy.

REFERENCES.

Coley, Paper read before the 3rd Internat. Conf. of Cancer research, Brussels, August, 1913; Weissenbruch, Brussels, 1914; Bloodgood, Ann. Surg., ii, 145; Mutel, Rev. d'orthop., 1913, v, 423; Burnham, Interst. Med. Jour., xx, 1021.

(*d*) **Intra-uterine and Obstetrical Fracture.**—True intra-uterine fractures are not frequent, but there are over forty in the literature. Children may be born with healed, ununited, or fresh fracture, and the cause may be fetal disease, deformities, or non-development, and trauma received by the child *in utero* or during birth. Intrapartum fractures occurring during childbirth often arise from instrumental or manual manipulations in artificial delivery. They may occur, however, during an otherwise natural birth, the contracting uterus forcing a limb against the mother's bony parts in such a manner that fracture results. These are all fractures caused by external violence.

Other intra-uterine fractures are based on predisposing causes, such as chondrodystrophia, osteogenesis imperfecta, fetal rickets, or even congenital syphilis. The two last I do not consider real causes of fetal fracture, but they may have some influence in causing pathological epiphyseal separations. Instances of congenital deformities with fused or excess toes, absence of fibula, etc., cannot be considered under a heading of fracture.

True intra-uterine fracture occurs in healthy individuals, and is caused by direct violence, as from blows or falls. Hamilton[2] says that it may also be caused by muscular action, but that this is usually preceded by some constitutional cachexia. He cites a case of compound intra-uterine fracture. Bunton[3] collected 32 cases of true fracture, most of which were from falls or blows. Most of these injuries are sustained in the latter months of pregnancy. In Smith's collection[4] of 44 cases, which includes all in the literature up to that time, only three were produced by penetrating objects, *i. e.*, gunshot, sickle, and pitchfork. Falls were responsible for 22 cases, blows for 10, and pressure for 1. One case of fracture of the forearm bones was accompanied by dislocation of the humerus. Thirty-eight cases in which the results for the mother and child were stated, showed two maternal and eight fetal deaths. The injury does not often interrupt pregnancy. In the collection mentioned 29 went on to term, 8 did not, and in 7 cases the result was not stated. In 32 of the cases the fracture was single, in 5 multiple. In all, there were 12 fractures of the clavicle,

[1] Med. Record, 1913, p. 650.
[2] Fract. and Dislocations, 6th ed., p. 31.
[3] Tr. Am. Surg. Assn., 1884, ii, 425.
[4] Surg., Gynec. and Obst., 1913, xvii, 355.

11 of the skull, 11 of the leg, 4 of the forearm, 4 of the humerus, 3 of the femur, and 1 of the scapula.

The fact that these fractures do occur may assume medicolegal importance in cases where the mother has been subjected to some violence. In the discussion of Smith's paper, Dr. Ries,[1] of Chicago, mentioned a case which had gone to court. A woman had fallen in a hospital elevator and the leg of her child was broken, an injury for which she sought damages from the hospital. Dr. Chas. Paddock had never seen a case but believed there were many which never found their way into the literature.

EXCITING CAUSES OF FRACTURE.

The exciting causes are: (1) external violence, divided into direct and indirect violence, and (2) muscular action.

1. Fracture by direct violence implies that the loss of bone continuity has occurred very near the site where the external violence is applied. The line of fracture may extend anywhere from this point, but that is its origin, unless there is a very weak point of the bone close at hand. Indirect violence, however, causes fracture at some distance from the point of application of force arising from compressional or torsional violence. This division of causes is an excellent clinical one, because it explains the great difference which exists between these two types. If sufficient force is applied to any part of the body to cause fracture of the bone beneath the soft parts, injury of these parts is always present. This may vary from extensive bruising with ecchymoses to laceration, open fracture, and gangrene of the tissues from excessive trauma. Occasionally the elasticity of the skin saves it from rupture, the soft parts and bone beneath are torn apart, and pressure necrosis of the skin may follow from the hematoma, although there are no visible marks of violence on it. Indirect violence results in a transmission of the force to a distant part of the bone or limb, so that the bone break is in another area. These fractures may also result in injuries of the soft parts; that is, the point where the violence is applied may be lacerated, or the parts about the site of bone separation may be injured and the skin punctured by sharp fragments forcing a way out.

2. Fractures caused by pure muscular action are not numerous. It is necessary to confine to this class those bone injuries which are caused by the exertion of the muscles through their insertion and not with the help of any external violence or restraint. If a man catches his foot in the frog of a railroad track and in the violence of his efforts to extract it in the face of an approaching train, makes violent muscular exertion, and these exertions result in a twisting of his ankle and fracture, or he throws himself to one side with sufficient force to break his leg, the result is not considered fracture from muscular

[1] Surg., Gynec. and Obst., xvii, 391.

action. The same ruling applies to fractures received from falls or collisions where the body momentum has been caused by muscular action in running or walking. A fall on the hand while one is running may cause fracture of the wrist, arm, or clavicle. The injury is not caused by muscular action, but to transmitted stress down the rigid arm meeting with the sudden impact restraint of the ground. The best illustrations of fracture arising from true muscular action are in the patella and olecranon by direct pull of the muscles on the bone causing it to be torn apart. When muscles and ligaments are resisting force applied to a limb, or parts of the body, this type of fracture results. Illustrations are offered in fractures of the anterior superior iliac spine, of the fifth metatarsal bone, of the tubercle of the tibia, of the vertebræ and the greater tuberosity of the humerus, etc. Other cases of muscular action with resulting fracture are found in accidents which are caused by great muscular exertions failing to meet the resistance expected. Excessive force in throwing an object which slips from the grasp may result in fractures of the humerus from the powerful action of the shoulder-girdle muscles. Likewise in kicking violently at an object and missing it, one may fracture the femur. In violent efforts of running with a misstep or slip, muscular action may pull off the lesser trochanter of the femur. The bones involved in these fractures are generally healthy and are those of robust adults. No abnormal changes in their structure are necessary, and this type of fracture is frequently found in routine Roentgen-ray examination. Muscular action may be combined with direct or indirect violence by being brought into play to resist stresses applied to a limb and become a contributory cause of fracture. The addition of muscular action may greatly increase fracture violence and its continuance afterward augment the displacement and local symptoms. It may also act in connection with pathologic conditions, as previously described, causing the final solution of continuity in a bone already weakened by disease.

GENERAL MECHANISM OF FRACTURE.

From a mechanical standpoint fracture can be explained on the basis of stresses and strains. This explanation is not easy to apply to clinical work, but is a suitable division of exciting causes. Trauma of accident or injury results in stresses transmitted to the supporting bones which can be analyzed into component compressive and tensile factors modified by various torsion, flexion, and shearing stresses. Combined with this elementary fact there are generally complicating shocks and vibrations like those caused in the jars of falls. These additional vibratory forces may produce rapidly alternating compression and tension which prohibit a simple mechanical analysis. The vibrations break and modify a bone when it is under severe strain of bending or torsion—almost at the point of giving way. This mechanism can be reduced to simple terms by comparing a long bone

subjected to direct violence, with a beam supported at both ends, carrying a load between. This has been explained by Rixford,[1] Pringle and others. Compressive stress made on the beam, *i. e.*, bone, on the side of the application of the load is equivalent to direct violence, the maximum force being expended at the point of application. This acts by compressing the beam at that point, while at a point directly opposite, supposing the force is acting at right angles to the long axis, there is a corresponding point of maximum tensile stress that is tending to tear the structure apart (see Figs. 6 and 7). On account of their structure long bones usually give way from tensile rather than from an equal compressive stress. Fracture by direct violence may be indicated schematically by Figs. 6 and 7. The usual line of fracture in a beam, even steel beams, is not exactly transverse, because the beam bends and gives way as the fracture progresses through its substance. This bending increases, and finally in the course of the fracture a point is reached where resistance to tensile stress in the transverse diameter is equal to or less than the tensile stress resistance

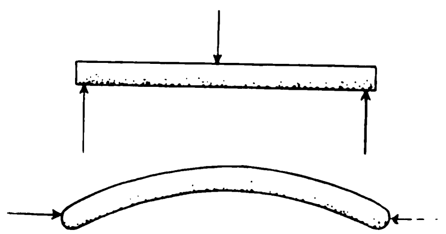

FIG. 6.—Illustration of direct violence applied to a beam in the transverse and in the longitudinal axis.

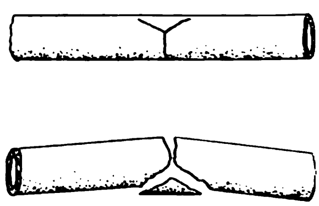

FIG. 7.—Result of direct compression on a beam. The planes of separation are frequently oblique, the small fragment being broken out on the side of application of the violence.

in the longitudinal axis, and the fracture line takes an oblique direction (see Fig. 8). If these two lines of fracture develop, they diverge from this point of application of force and the beginning point of fracture separation on the convex side of this bending curve. They pass toward the concave side, and as a result a triangular-shaped piece, like a wedge with its base on the concave side of the bend, is broken out. This wedge may be comminuted into several pieces and confirm Bardenheuer's observation that the loose fragment is always on the side of the concavity of the deformity. Both these diverging lines of fracture may not be complete; one may be a mere fissure with no separation, a case in which the fracture becomes a true oblique fracture caused by bending or flexion of the bone. These are seen in the humerus and femur, the line starting at the tuberosity and passing down and inward obliquely, and are caused by flexion over some object used as a fulcrum, as a heel in the axilla during attempted reduction. Another variation is sometimes found in cases where the transverse

[1] Jour. Am. Med. Assn., lxi, 916.

cohesion or tension strength resistance is low compared to the longitudinal. A mild bending of the bone may cause a longitudinal split or separation with both ends of the fracture line opening on to the concave side, the broken piece being pushed or squeezed out away from the shaft of the bone (see Fig. 9). Occasionally a direct, sharp, quick blow with bending results in a completely transverse line of fracture. If these fractured ends are examined, incomplete diverging fissures will be found which run upward and downward along the bone from the transverse fissure. These lines obey the mechanical

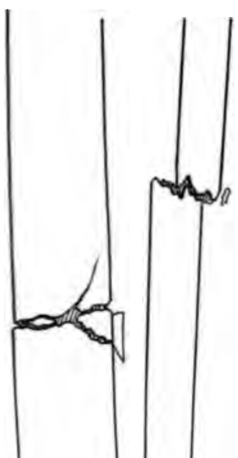

FIG. 8.—Fracture of both bones of the leg from direct compressional violence. Note the oblique planes forming and the loose fragment broken out.

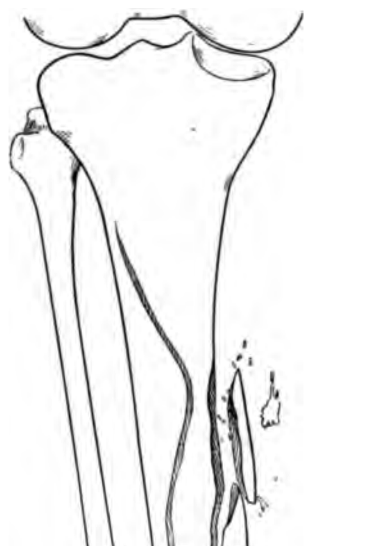

FIG. 9.—Direct compressional violence applied to the tibia resulting in fracture with longitudinal splits opening on to the concave side of the bending bone. A piece is squeezed off the shaft at this point.

law expressed above, and they always seem to take origin at that side of the bone which corresponded to the convexity of a curve produced by the force.

Pure flexion fracture results from a direct violence applied at right angles to the bone shaft. If the force is not perpendicular, but comes from an angle, torsion and twisting are introduced into the mechanism. Flexion fracture may also be caused indirectly by two forces acting at opposite sides of the bone shaft, one at each end. Two forces acting on opposite sides of the same level produce a comminuted fracture with

little displacement, but if one force acts on a slightly higher level than the other, a transverse fracture with lateral displacement results. This has been called a shearing fracture (Fig. 10). The best example of this shearing type is found in the talus. Falls on the hyperflexed foot cause the sharp anterior articular edge of the tibia, driven by the momentum of body weight, to cut off the head of the talus. The body of the bone is crushed and pushed out backward, the sheared off head finding displacement anteriorly.

Green-stick Fractures.—It has always been considered that children's bones, because they were softer and more elastic than adult bones when subjected to bending strain, would split partly in the transverse axis and then suffer longitudinal cracks and fracture with further bending of the unbroken portion on the concave side. This is the type of fracture found in green wood with a longitudinal grain. As a matter of fact, however, this type of fracture is very rare even in children, because the lateral cohesion of bone is relatively large, and although most fractures of children's long bones are caused by bending they are not incomplete fracture across the transverse axis. Most of them are complete fractures, transverse or oblique, the ends are splintered by the incomplete fissures previously described, and the displacement is usually only angular. Some are *buckling* or *compression* fractures of one side of the shaft, if the force is expended in a longitudinal direction only or is not sufficient to cause any more cracks or carry its lines of separation to the concave side of the bend. We know that the compacta causes rigidity and stiffness in long bones. Children's bones have a thin compacta which does not extend as far toward the articular ends as in adult bones. The cancellous tissue extends farther from the epiphyses in children also, and it is in this area of cancellous bones with a very thin compacta that the bone breaks incompletely by buckling on the side subjected to the greatest compressive stress. Of 17 incomplete fractures of the radius and ulna recorded by Rixford 8 were typical buckling fractures, one to one and a half inches above the epiphyseal line; 6 buckled on the dorsal and 2 on the volar surface. Epiphyseal separations are always due to tensile stress, which pulls them off by means of ligamentous insertions, the area being too soft to break.

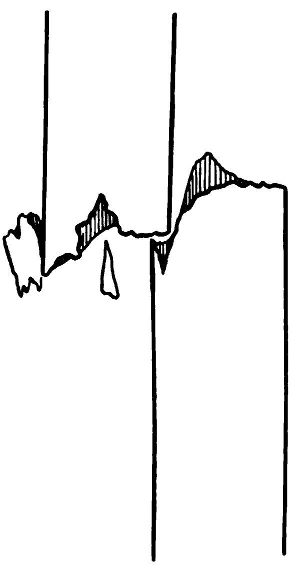

FIG. 10.—Shearing fracture in the femur. Transverse with lateral displacement.

Buckling occurs in the radius and humerus most frequently. I have a roentgenogram (Fig. 11) of one rare case of buckling fracture from longitudinal compression, apparently involving the whole circum-

ference of the upper end of the shaft of the humerus. Rixford says the only true green-stick fracture he ever saw was in a man aged twenty-eight years. I have seen one in a man aged forty years. Children's bones are tougher and more elastic than the brittle bones of adults, the periosteum is thicker and more yielding, and there is generally a thicker pad of subcutaneous adipose tissue to take up jars. If applied violence is sufficiently strong, transverse fractures occur in children as well as in adults. If the force is not sufficient to cause complete fracture, the child's tough and elastic bone yields, and the process ceases when it reaches a point short of complete separation, the splintered fragment ends interlocking and preventing lateral or rotatory displacement but permitting angular displacement. This may occur without rupture of the periosteum on either side of the bend, but the fracture is not a green stick break, rather a subperiosteal fracture. Roentgenograms of so-called green-stick fractures after healing show callus formation on both the concave and convex, or greater separation side, verifying the transverse solution of continuity.[1]

Fig. 11.—Buckling fracture involving the whole circumference of the upper humeral shaft, caused by longitudinal compression.

Familiarity with green-stick fracture has practical importance in treatment. Because these fractures are complete and not green stick, do not manipulate them and produce more displacement by increasing the angularity, but simply press them back into alignment. A true green-stick fracture will have shortening from compression on the concave side, and it should be broken clear across by exaggeration of the angular deformity, but the periosteum must not be ruptured in the process. It acts as a guard to hold the osteoblasts within the bone contour.

Fractures Caused by Torsional Violence.—Torsional violence may act on a limb in two ways. It may be applied at the periphery of the limb, the proximal portion remaining fixed, or the peripheral portion may be fixed and the torsion applied through the proximal portion. The common examples of these mechanisms are seen in the leg. The leg is fixed and the foot is twisted outward, the torsional violence being applied at the periphery. The foot is fixed and the body is twisted and swung around transmitting torsional stress to the upper part of the leg, *i. e.*, the peripheral portion is fixed and torsional violence applied to the proximal portion (see Fig. 12). These mechanisms result in spiral fractures, not oblique fractures, which are really rare and occur from direct compression violence, as previously described.

[1] Cotton, Bost. Med. and Surg. Jour., November 29, 1906, p. 553.

Oblique fractures have the angular points of the fragments on opposite sides of the bone; spiral fractures more frequently have the points on the same side, and in the case of the tibia on the rear surface. Spiral fractures result most often in the leg, then in the femur, then in the humerus, etc. The humerus suffers less frequently because dislocation occurs many times at the shoulder before the shoulder-point is fixed to permit spiral fracture of the bone. In the forearm also the bones are more readily dislocated than fractured spirally.

Kocher and Zuppinger,[1] and Zuppinger-Christen[2] first explained this mechanism. The shaft of a long bone is comparable to a hollow cylinder of nearly uniform construction (Fig. 13). When such a cylinder is subjected to axial torsion beyond the point of elastic limit it breaks, and the line of fracture is a spiral. The spiral takes the same direction as the torsion; that is, spiral fracture is either right- or left-handed. When the axial torsion is applied, tensile stresses develop on the outer surface of the cylinder which are counterbalanced by compression stresses on the interior surface as long as the torsion does not overcome the limit of elasticity. When the bone breaks, the line of separation extends along and around the shaft in spiral form and may pass once or twice completely around the circumference (see Fig. 14). As the bone gives, starting from some weak point it tends to unroll in its longitudinal continuity, and as it does the tensile stress is shifted to the inner surface of the cylinder and the compression stress passes to the center (Fig. 15). As the spiral or screw fractures proceeds in its unfolding along the bone, flexion becomes a factor. The force of torsion loses some of its effect, and the flexion combined with it causes a longitudinal line of fracture connecting the spirals. As a rule, in the tibia the spiral separations are on the anterior surface of the bone, both on the same aspect, and the longitudinal line is on the posterior surface, so that each fragment ends in a sharp or wedge-shaped point, the two lying vertically one above the other. This differs from the true oblique fracture described previously. The spiral line may continue as an unseparated fissure beyond the ends of the fragments. On account of greater elasticity the line of spiral fractures in young bones is steeper and longer than in old bones (Fig. 16). Increased spiral pitch is also found in small bones as compared with large. At the site of the spiral separations the periosteum is always

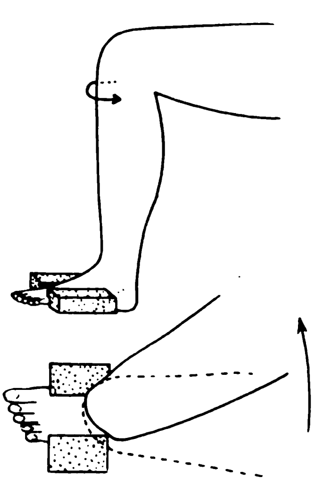

Fig. 12.—Affect of torsion on the leg when the body is twisted and the foot is fixed. Adapted from Zuppinger.

[1] Beitr. z. klin. Chir., 1906, p. 301; 1909, p. 562.
[2] Allgemeine Lehre von den Knochenbrüchen, Leipzig, 1913, p. 26.

orn apart. It may remain intact in the longitudinal portion of the acture, unless there has been additional longitudinal force, which

Fig. 13.—Arrows dicate the direction of torsional violence applied to a ollow cylinder cened to a pipe-em bone.

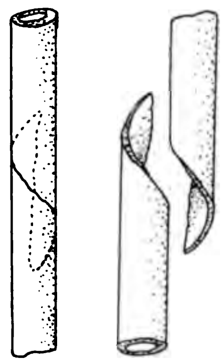

Fig. 14.—The spiral manner of separation from torsional violence. The two points of the fragment lie vertically one above the other on the same surface of the cylinder.

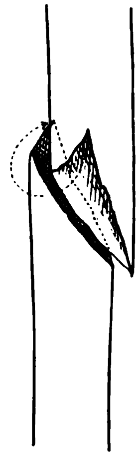

Fig. 15.—Pure spiral fracture in the humerus. Note the rotary displacement.

ig. 16.—Incomplete spiral fracture of the tibia of a young person.

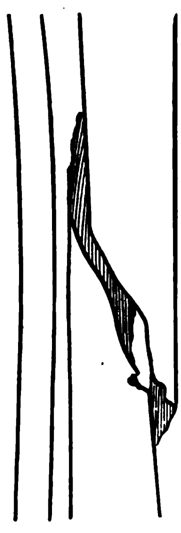

Fig. 17.—Steep spiral fracture of the tibia.

roduces shortening and stripping up or tearing. Clinically spiral ractures are rarely of pure type, because many are received while

the patient is standing. Longitudinal force of weight-bearing and muscular action may continue to act after the torsional violence has eased off and may cause periosteal stripping, comminution, or an open fracture, by driving the pointed fragments out through the soft parts. The flexion action which begins as the leg loses support (Fig 17) from the spiral separation, may cause a quadrilateral-shaped piece of bone to be pressed or squeezed out on the concave side. Pringle says this piece is entirely comparable to the triangular piece of bone found on the concave side in a flexion fracture. In the leg the fibula may also be broken or not. This depends on the degree of torsional violence and the elasticity of the fibula. Consequently in young individuals we would not expect the fibula to be broken often. If it is broken by torsion, a spiral fracture above the line in the tibia is expected; if it breaks because of flexion after the tibia has given way, we may look for the transverse or oblique fracture. Spiral fracture of the fibula alone does not occur except in the external malleolus; it is caused by torsional violence from external rotation of the foot and ligamentous pull.

In the chapter on Fracture of the Bones of the Leg attention is directed to the finding that spiral fractures are usually left-handed in the right leg and right-handed in the left leg. This same observation can be made of spiral femur and humerus fractures, the cause existing in the fact that the foot or forearm, the mobile peripheral portions, project forward and outward and in injuries are more exposed to outward rotation. The other leg tends to prevent inward rotation, and the forearm by striking against the trunk acts the same way in the upper extremity. Consequently this rule holds, whether the peripheral segment of the limb is turned outward upon the fixed proximal portion, or the peripheral segment is fixed and the trunk becomes mobile and is rotated in the opposite direction. Right-handed spiral fractures in a right extremity could occur only under the rare conditions that the peripheral segment was rotated inward contrary to ordinary mechanism or the peripheral portion was fixed and the mobile proximal portion was rotated outward.

CHAPTER III.

PATHOLOGY OF FRACTURE.

I. THE BONE.
  Types of Fracture:
    1. Complete, subdivided according to—
      (a) The plane of fracture, into transverse, oblique, spiral, longitudinal, comminuted and V-, Y-, and T-shaped.
      (b) The site of fracture, into shaft (diaphyseal), neck, epiphyseal, inter- or supracondyloid, malleolar, intra-articular, fractures, sprain fractures, and splinter separations.
      (c) The displacement, into transverse, angular, rotatory, overriding, impacted, longitudinal, and crushed.
    2. Incomplete, subdivided into—
      Green-stick or true incomplete fracture, fissures, depressions, punctures, and buckling.
    3. Closed and open fractures.
    4. Multiple fractures, involving the same or different bones.
    5. Gunshot fractures.
II. THE SOFT PARTS.
III. COMPLICATIONS AND SEQUELÆ.

I. TYPES OF FRACTURE.

1. **Complete Fractures.**—All fractures may be divided in accordance with their local pathology, as they are usually a manifestation of trauma, or of indirect violence, and do not depend on constitutional disturbance. Complete fractures are those in which the bone fragments are separated by a plane crossing through the bony substance.

(*a*) **Plane of Fracture.**—The direction of the plane offers a mechanical subdivision. The direction may be transverse, oblique, spiral, longitudinal, comminuted, and V-, Y-, or T-shaped. In the chapter on Etiology and Mechanism an attempt has been made to explain some of these planes of fracture from a physical standpoint. Uncomplicated examples of these various direction planes are not common. As we have seen, the lines of force become complicated as a bone gives way under breaking compression and tension force, and the result is the formation through the osseous tissue of new lines or planes complicating the original plane. Transverse fractures are those which correspond within a few degrees to the transverse axis of bone. Oblique fractures are those the plane of which passes through the bone at an angle from 40 to 70 degrees. There may be two planes, as described previously, with the breaking out of a pyramidal-shaped bone fragment. Simple oblique fracture is not common. Either one of these two varieties may show a rough and splintered surface when the fracture site is opened or when a roentgenogram is studied. If the whole plane of separation is irregular with many projections, it is called toothed or dentate.

Spiral fractures occur in long bones. The tibia, fibula, femur, and humerus are common sites, and the cause is torsional stress. From an understanding of the mechanical causes of torsion or spiral fractures we know that the usual plane of separation of the spiral is right-handed in the bones of the left extremities and left-handed in the right extremities. The planes of fracture as a rule in pure torsion fracture start and end on the same surface of the bone, differing from oblique planes, which start and end on opposite surfaces. If compression and torsional stress are combined in the cause, one may expect irregular planes of fracture, or comminution.

Longitudinal planes are an exaggeration of oblique planes. This form of traumatic bone separation is rare. They are found when a limb has been subjected to great violence as falls from a height or a splitting force applied in the axis of the chief lamellæ. In many instances they are complicated by crushing and impacted conditions of the bone at the joints. The separation of fragments varies; usually it is not great and runs off at one end into a fissure of incomplete fracture. Wide separations are troublesome; they are difficult to reduce, and the subsequent thickening of the bone leads to complications which interfere with the function of the limb.

Comminuted fracture is the term applied to a bone broken in several pieces. In addition to having a distinct plane of separation which represents the major action of the force, the bone in the vicinity is broken up or splintered by the action of the combined stress. Comminution is a term also applied to fractures of flat bone, like the scapula or the vault of the skull, when several irregular large fragments are broken off or out of the bone. There may be no splintering or crack coexistent.

The terms V-, Y-, and T-shaped are applied to fit the shape of a broken out fragment, or the direction of the plane of separation. V-shaped fractures are found in the shafts of long bones and are due to compressional violence (see Etiology and Mechanism). Y- and T-shaped fractures are found near and into joints.

(*b*) **Site of Fracture.**—The site of fracture also offers a basis for subdivision. For convenience one often labels the fracture according to the part of the bone involved, and as any part of the osseous structure may suffer complete separation there is a corresponding nomenclature. There are fractures of the shaft, neck, malleolus, inter- or supracondyloid between or above the condyles of the humerus and femur. Sprain fractures, which are caused by the pulling out of strong muscle of ligament insertions, are usually near joints. They may affect any bone with these insertions, and are often so minute and delicate that they can be made out with difficulty. They are, however, real solutions of bony continuity and require sufficient protection and rest to give time for bony union.

Splinters may be separated by direct violence from parts of the bone, either near the articular ends or from the shaft. Direct violence and ligamentous pull tear these off, and the displacement may be very

wide. Examples of tearing separation are furnished by fractures of the tuberosities of the humerus, the iliac spines, the trochanters of the femur, and other points subject to great muscular strain. The separation varies (see illustrations of these mentioned examples).

Articular fractures are those in which the plane of separation in some parts of its course enters into a joint. The separation is of varying degree and consequence. A fissure through the bone substance may continue from a fracture plane near a joint, pass through the bone, and stop just under the cartilage and synovial surface. Strictly speaking this would not be an articular fracture, but for all practical purposes it is so. In more pronounced cases there is a splitting apart of the joint end of the bone, tearing the joint surface through and resulting in a hemarthrosis, without tearing the joint capsule. A final stage is represented by T-, and Y-fractures found in the lower end of the humerus and femur, in which articular fragments are broken off and pushed asunder, with wide tearing of the joint capsule and a driving down of the broken shaft into the disrupted joint. Intra-articular fracture is a term which should be applied in a limited sense to solutions of bone continuity taking place entirely within the joint. Fractures of the femoral neck within the capsule, of the olecranon and patella, of articular portions of bones like the femoral and humeral condyles, are in this division. Fractures of the carpal and tarsal bones which really lie within a joint must be included in this division when their pathology is studied. (See drawing representing schematic arrangement of synovial surfaces under the heading of Wrist Fractures.)

The pathology of intra-articular fractures concerns the joint structures as much as the articular fractures. The capsular ligaments may not be disturbed, or they may be widely torn. Likewise, there may be hemarthrosis, aseptic inflammation, and joint distention, infection, and pyarthrosis. The turning of a fragment or a small amount of excess callus, the contraction and implication of periarthritic structures may interfere seriously with joint function. The broken-off bone fragment may be absorbed by pressure or action of the synovial fluid, or its presence may prolong the periarticular irritation and loss of function. This is particularly true in many carpal and tarsal fractures and is not a widely known pathological fact. Intra-articular fragments may mechanically interfere with joint motion from the time of accident, or, by reattachment to bony or capsular surface, at a later period. The articular fractures are those which enter the operative class at the very first, and with an understanding of their pathology the surgeon may often make a decision for early removal of fragments or of a whole bone, rather than delay until periarticular changes and prolonged disability demand open operation.

Epiphyseal separations are now known to be an every-day occurrence. They are found in any bone from the femur to the phalanges and must be considered in all differential diagnoses of fractures near joints. The plane of separation is usually through the cartilaginous

area of the growing epiphysis, although these separations are present up to the time of complete ossification of the various epiphyses. After calcification a plane of fracture is likely to select the old epiphyseal region, if the stress applied is cross pulling and twisting near the ligamentous insertions around joints (see Fractures at the Wrist, etc.). A ragged edge marks the disjunction of the epiphysis from the diaphysis and the plane of fracture in complete separation frequently varies to extend a short distance through the diaphysis.

Separations may be complete or incomplete. The epiphyseal plane may start to separate along one edge of the bone and cease before the whole diameter is involved, or the fragments may be but slightly started from their position and have an inconsequential separation. Complete separation with sliding of one fragment over the other is also of different degree. When there is shifting, the periosteum is ripped up from the diaphysis for some distance. It may retain its attachment to the epiphysis and move out of place with it, or it may be torn across and left lying in natural contact with the shaft. I do not believe torn periosteum ever seriously interferes with reduction of epiphyseal separations by interposition. The diagnosis is not difficult clinically in the ends of long bones. In the neck of the femur its decision may be impossible without a roentgenogram. The cases are characterized by displacement in the vicinity of a joint, or of a known epiphyseal plane. The joint prominences themselves are intact. There is no crepitus, and the swelling and tenderness lie at the epiphyseal site. A perfect reduction of an epiphyseal separation gives a correspondingly good prognosis. There are a few cases in the literature which have caused interference with growth of a long bone, but when one compares them to the great number of epiphyseal separations which occur, there seems to be little danger of interference with growth. I have several epiphyseal separations at the wrist and ankle under observation and have never seen a case of growth disturbance. Theoretically one might expect infections and abscesses to follow these injuries, because organisms in the blood stream would tend to settle and thrive in the traumatized area. Clinically this is not so. Under the heading of each bone discussed some attention is drawn to the various epiphyseal planes and the frequency, causes, symptoms, and treatment of their separations.

(*c*) **Displacements of Fractures.**—The types of fractures are also divided according to the character of the displacement of the important fragments. These displacements are transverse, angular, rotatory, overriding, impacted, and longitudinal. There is also longitudinal crushing or buckling. There may be various combinations of these pathological states. It is usual to find rotatory displacement associated with other forms, because body weight acts in the mechanism after violence has caused a solution of bone continuity. The pressure of the body on a limb results in torsion stresses from muscular pull when the normal bony support within the part is lost. Likewise overriding and impaction may be combined.

Transverse displacement is a lateral shifting of the fractured surfaces on each other so that their long axes do not coincide. This change may take place in any direction toward either side or backward or forward. It is incomplete when the fractured ends are shifted but not completely separated. Generally there is complete separation, and the fragments have an angular deformity or ride past each other.

Angular displacement is shown by the formation of an angle at the site of fracture by the axes of the two main fragments. This angle may be of any degree up to 90, and the fragments may come to lie one against the other, forming a right angle. The whole amount of angular displacement is not caused by the fracture violence as a rule. Gravity, body weight, and muscular action add their effect after the bone separates.

Rotatory displacement signifies that the fragments turn on each other in their long axis. As described in the chapter on Mechanism of Fracture, this rotation in an extremity usually concerns the distal portion which is turned outward and at the fracture site the distal fragment is usually the one rotated, although both may be rotated when unbalanced muscles come into play after the fracture of the bone.

Overriding of fragments past each other is caused by body weight and muscular action after transverse, oblique and spiral fractures. Hemorrhage and traumatic swelling within the tissues may increase the displacement. The continuance of the force in falls on an extremity or torsional violence may also produce overriding and it is difficult to analyze the different factors. In cases of extreme overriding all three factors undoubtedly come into action. The pathology in this condition is more extensive than in fracture with less displacement. The periosteum is torn or stripped up, muscles and fascial sheaths are ruptured, there is more hemorrhage.

Spiral fractures with overriding lead to fractures opened to the air from within by sharp points of bone.

Impaction displacement signifies complete fracture with an immediate subsequent ramming penetration of the fragments whereby they are driven together and the bone lamellæ are crushed into each other. During the momentary separation the axes of the fragments are usually changed so that when the portions are united by impaction there may be angularity or transverse displacement.

Longitudinal displacements are of two kinds. One is complete and concerns separation found in fractures of the patella and olecranon. This kind is caused by muscular and tendinous contraction, by swelling of tissues, and by the distention of joint cavities by blood. The second type of longitudinal displacement is incomplete and may be described as a crushing or telescoping of the bone in its long axis. Some lamellæ are crushed into each other, others are forced out at a wide angle from the former axis, and the bone is shortened in its longitudinal axis. This type of fracture is sometimes called a buckling fracture. See remarks on mechanism of fracture.

2. **Incomplete Fractures.**—Incomplete fractures are divided into true incomplete or green stick fracture, fissures, depression, punctures, and buckling fractures.

Green-stick Fractures.—Green-stick fractures have been discussed in the chapter on Etiology and Mechanism of Fracture. The bone is separated by a splintering on the concave side of the bend induced by violence, the other side suffering no change at all or a slight compression. True green-stick fracture is rare and is replaced by being pushed back into alignment. Healing rapidly follows, and there is no displacement and deformity. Infraction is a term also applied to this type of bone bending. It illustrates fully the mechanism of bending fracture. There is a small transverse line of fracture or separation accompanied by multiple longitudinal lines which pass into the long axis of the bone. The periosteum is seldom ruptured. There is some swelling at the site of fracture from the interstitial hemorrhage and distention of the periosteum.

Fissures.—Fissures in the bone are closely allied to green-stick fracture. They are long cracks in the bone substance without much displacement. These fissures may be oblique, spiral, or longitudinal. In long bones they are seldom found alone but usually in connection with complete fracture, some of the extended lines of force splitting open the distant portion of the shaft. The periosteum may be torn or not; over the fissure area it is generally uninjured. Isolated fissures are seen in long bones, in the tibia and humerus. They are characterized by pain, soreness, and loss of function, out of proportion to physical findings of the bone concerned. There is no displacement, crepitus, or deformity, and the full extent of the crack can be determined only by the roentgenogram, although the extent of the persisting line of tenderness furnishes a clinical basis for measurement. Fissures opening into joints frequently cause hemarthrosis distant from a fracture site. They are important in cases of operated fracture, as they may interfere with the application of internal splints. In skull injuries, fissures are of great importance. A large percentage of basal fractures are fissures, the bone lesion being of little importance, the hemorrhage consequent to the slight bone separation from torn vessels having much significance. The slow oozing and gradual increase of intracranial pressure interferes with cerebral function, results in edema and coma, and may lead to a fatal termination. Fissure in the pelvic bones may also be of significance on account of the contained viscera.

Depressions and Punctures.—Depression is the term applied to a limited area of crushing which involves the surface of a bone and does not form a complete plane through its substance. Small depressions, usually linear in character, can be found on the broad surfaces of the tibia, or on the enlarged ends of bones like the femoral condyle. They are caused by direct violence, the compact layer is depressed into the medullary portion beneath, the harder compact surface retaining its form while the trabeculæ of the medulla are crushed to permit the

displacement. Depressed fractures of the skull illustrate this condition. The presence of the spongy diploë permits the outer table to be broken down and depressed below the surrounding surface without injury to the inner table. Both tables may be involved. These fractures are frequently spoon-shaped or circular.

Puncture fractures are caused by the impact of a sharp point which is driven down into the bone substance. Pitchfork points, bayonets, knife blades, or bullets, are examples. The outer surface of the bone first struck may be depressed by the object and carried down into the mass of bone. The pathology is usually a separation of the bone trabeculæ which permits the object to pass within or possibly through its substance. If the puncture is simple, it heals promptly. It may lead to deep infection in the bone or cause splitting and comminution for some distance.

Buckling fractures have been described previously under the pathology of complete fracture and in Etiology and Mechanism.

3. **Open and Closed Fractures.**—A division of fractures is made on the basis of the presence or absence of a wound in the skin and soft parts which leads to the fracture. A wound of the soft parts overlying the broken bone is caused by violence from without or puncture of the parts by a sharp fragment of bone from within. These fractures have been called compound and simple. The terms open and closed are more specific, they are intelligible to laymen, and their simplicity has led to their adoption. In 10,702 fractures at the Cook County Hospital which I have studied there were 379 open fractures.

A closed fracture has considerable local pathology. It means injury and loss of continuity of the osseous tissue and to a certain extent injury to surrounding soft parts. There are blood extravasation and the phenomena of aseptic inflammation. Closed fracture may become open fracture in a few days, if the soft parts become gangrenous and slough, or if a splint unwisely applied presses against the swollen tissues and causes the same result. Open fractures may also occur in the course of repair of closed fracture, if the patient becomes delirious or unruly and throws the limb about, opening the soft parts by projection of a bone fragment from within. Open fracture conveys the idea of an opening or wound through the tissues covering the bone. Such an injury contains all the pathology of a closed fracture, and in addition invites primary infection from the causative trauma, or secondary infection from the access of air and external dirt through the skin to the depths of the wound. Any fracture with loss of skin continuity, even though it is not immediately over the site of bone injury, must be considered as an open fracture. It is impossible to say whether the opening in the soft parts leads indirectly to the bone lesion, and in many instances it is unwise to probe to ascertain this connection. The soft parts may break at a different level; the intervening clot which forms may partly drain out and partly act as a barrier to prevent deep infection. In some instances, especially when the soft parts are wounded by a fragment penetrating from within

outward, conservative treatment of non-interference is the best, because there is less opportunity for infection in injures of that type. (See Treatment of Open Fractures.) The shock of open fracture is generally greater than that of closed. Hemorrhage may in part account for the difference. A certain proportion of open fractures, more often those opened from within, heal as rapidly as the closed fracture. The drainage of the hematoma about the fracture site, in the absence of infection, favors early union. This point is discussed in the chapter on Bone, under the heading of the Healing of Open Fractures. In the chapter on Treatment, the question of and indication for amputation and operation are considered at length, and under the heading of each bone specific open fractures are discussed.

4. **Multiple Fractures.**—Single fracture is a term rarely used. Multiple fracture is a term applied to two conditions. The same bone may be broken in more than one place with no connecting plane, or two or more bones may be broken simultaneously, although at a distance from each other. When a bone is broken in two or three places the condition is often called double or triple fracture. Extensive comminution of a flat bone like the scapula or fracture of several ribs is called multiple fracture. Usually multiple fractures are more serious than single fractures, because they are the effect of a greater violence and the cause of greater shock. Consequently the prognosis varies with the multiplicity of the breaks, not so much on account of the bone lesions as on account of the increased shocking effects. A dozen fractures in different parts of the body will heal as quickly as a single fracture, if the patient overcomes the primary shock of injury and possesses no constitutional or local reasons for delayed union.

5. **Gunshot Fractures.**—Gunshot fractures are really a division of open fractures caused by bullet wounds. They are a well-defined type, and though they are subject to all the pathological conditions of ordinary open fracture, they are also for some reasons a favored class. Bone destruction is minimized by the modern high-velocity bullet. When this bullet strikes on the edge or flat surface of bone, it may burrow it or break off a spicule, but it does not spread like soft-nosed bullets and rarely causes great comminution of the osseous structure. Striking in line with the transverse axis of a bone it may cause a transverse fracture, or may penetrate it cleanly, leaving a small opening, or cause a slight degree of comminution. If the bullet traverses the longitudinal axis of a bone, it causes extensive comminution. Bullets nearly spent may strike a bone and fail to cause a complete fracture. Splits and fissures or breaking off of shells from the surface are common results. After it has been injured in this way a long bone may break under the strain of use.

From a pathological standpoint the greatest interest lies in the accompanying injuries of the soft parts. Infection in the bullet track stands out as of foremost importance in regard to prognosis and treatment. Since the inception of the war of 1914 many eminent surgeons have spoken on the treatment of gunshot fractures. Goebel

classes all infections which are not received from the bullet itself as secondary, the bullet alone causing primary infection.[1] This is contrary to the opinion of many other men. Many gunshot fractures, particularly those caused by a pistol in civil practice, are relatively clean and do not often lead to serious infections. At the Cook County Hospital we receive many gunshot fractures, and there have been no amputations for infections from this source in two years. In war there is a large proportion infected, and first treatment must be directed toward combating the infection. Drainage and a minimum amount of operative interference with immobilization are indicated. Mr. Robert Jones[2] decries any attempt to use internal fixation in gunshot fractures, and advises immobilization in splints like the Thomas, or slings for the arm which permit free drainage, and he does not employ a plaster encasement which becomes fouled with discharges. Chaput,[3] Bonnette,[4] Korundjy[5] and Watson[6] give descriptions of methods of improvising splints for gunshot fractures in different parts of the body and also of methods for after-treatment.

Fractures caused by shots from shotguns at close range are serious on account of the injury of the soft parts. I have had three cases in the last six months, one of the humerus and two of the pelvis. All three had a fatal termination from complications and sepsis of the soft parts. Immediate amputation might have saved the arm case, but it did not seem advisable, because there was no nerve injury and the circulation of the arm was satisfactory, although the bone was blown to bits. Gunshot fractures of the skull are considered in the chapter on Skull Fracture.

In civil practice gunshot fractures from bullets do not give a greater mortality than open fractures from other causes, and they frequently heal quicker and have fewer complications. The subject of fracture caused by shell fire or shrapnel is not entered into here, because the injury in those cases is one of the soft parts primarily. Text-books of military surgery cover these points.

Pathological fracture is discussed in the chapter on Etiology.

II. THE SOFT PARTS.

Fractures sometimes occur without injury of the soft parts. The femoral neck may be broken within the limits of the capsular ligament with no injury of the soft parts. Ordinary fracture of any bone, however, is accompanied by pathological conditions in the surrounding parts. Previous reference has been made to the fact that there may be a solution of bone continuity without tearing of the periosteum. This condition is present in green-stick fracture or infraction. The

[1] Beitr. z. klin. Chir., 1914, xci, 373.
[2] Brit. Med. Jour., London, January 15, 1915, No. 2820.
[3] La Presse Med., September, 1914, No. 66.
[4] Ibid., August 12, 1914, xxii, No. 62.
[5] Ibid., August 26, 1914, No. 64.
[6] Lancet, London, October 10, 1914, No. 4754.

periosteum may be stripped up and loosened from the bone surface, or distended by hemorrhage from the ruptured osseous vessels and still maintain its continuity. This form of subperiosteal fracture is found in adolescents who possess a thick, resilient, vascular periosteum. The periosteum suffers every degree of laceration up to complete circumferential tearing, which is rare and found only in instances of great overriding displacement. Operative treatment of fracture has proved conclusively that periosteal shreds or bands between fragments persist in nearly every instance.

Muscles, nerves, and bloodvessels surrounding a fracture site may similarly receive no injury, or they may be completely severed. In direct violence muscles and fascial sheaths are torn by compression. They may be injured by displaced bone fragments which puncture and lacerate them, causing loss of continuity and hemorrhagic oozing. Nerves and bloodvessels are likewise injured. Secondary results from these injuries are not frequent and are considered under the head of Local Complications. Pressure within a limb in a closed fracture, or tight bandaging and splint application, also lead to complications of the soft parts.

The primary violence may rupture the skin or contuse it so that it sloughs and leaves an open wound. It may be punctured from within. In closed fracture, as the swelling follows from extravasation about the fracture, the skin becomes tense and shiny, as in inflammatory conditions. Its blood supply is diminished. Ecchymoses become apparent within two or three days, as the blood penetrates out toward the surface, and because this blood percolates along fascial and skin planes, a whole limb may show discoloration from fracture. Blebs filled with clear serum or deep colored blood are commonly found on the skin within a few days after fracture. They are so usual that they cannot be considered a complication. But by infection or sloughing they may result in serious complication, and by their presence they frequently preclude extensive splint application or operative treatment.

III. COMPLICATIONS AND SEQUELÆ.

Complications and sequelæ are divided into general and local.

General Complications.—Early:

1. Pneumonia and pulmonary edema.
2. Fat embolism.
3. Delirium tremens.
4. Tetanus.
5. Shock and death.
6. Sepsis.

Late general complications:

1. Postural and weight-bearing changes.
2. Neurasthenical states.

Early local complications: Lesions which involve muscle, including Volkmann's contracture, nerves, and bloodvessels.

Late local complications:

1. Callus and displacement complications:
   (*a*) Excessive or painful callus.
   (*b*) Weak callus.
   (*c*) Delayed union.
   (*d*) Non-union and pseudarthroses.
   (*e*) Vicious union and deformity.
   (*f*) Nerve injury and inclusion.
   (*g*) Development of tumors.
2. Arrest or exaggeration of bone growth.
3. Neighboring joint complications, stiffness, reduction of motion.
4. Muscle and soft part changes, stiffness, inelasticity, fixation.
5. Bloodvessel complications, thrombosis, embolism, and aneurism.

Early General Complications.—1. *Pneumonia and Pulmonary Edema*—Pneumonia and pulmonary edema are common complications of fractures. In the 10,702 fractures used as a basis for this book, there were 122 cases complicated by a lobar pneumonia, and 40 by pulmonary edema, as far as the clinical examinations could determine. Pneumonia may arise from exposure after injury, blows on the chest, or confinement in bed. Onset within the first forty-eight hours is usual, and the course is rapid, with a high temperature and general toxemia. This complication must be considered before anesthesia is given for early open operation or reduction of fracture by extension apparatus. The records of the Cook County Hospital are not in a condition which would warrant determination of the relative proportion of cases of pneumonia following the administration of anesthesia for operative and reduction purposes during the whole period of this series of fractures. Fat embolism plays little if any part in the production of pneumonia. (See Fat Embolism.)

Pneumonia and hypostatic congestion or pulmonary edema are found as complications occurring within a period of four days to two or three weeks after fractures in elderly patients. I have seen one case starting in the seventh week. Confinement to bed and a recumbent position for fracture of any bone is the principal cause. The course may come on insidiously, with little fever and no cough. Prostration and delirium follow, and the patient may pass away quietly in a condition of great weakness.

2. *Fat Embolism.*—Free fat may enter the circulation from the subcutaneous adipose tissue, the liver, or from the medulla of bone following traumata. It is a clinical fact that fat is found in the urine for two or three days after many fractures and it is possible that every fracture is followed by some injection of fat droplets into the general circulation by way of the veins or lymphatics. To cause symptoms or a fatal result the absorption of large quantities of fat is necessary. A sufficient amount cannot be found in the bones of youth under twelve or fourteen years of age. In adults when the medullary cavity which contains liquid fat is traumatized, a sufficient quantity of fat may be thrown into the general circulation to cause fat embolism. Many

cases of fat embolism have been reported by orthopedic surgeons after bloodless manipulations for congenital dislocation of the hip. The bones manipulated under these circumstances have been out of function for a long time and have undergone degeneration in accordance with Wolff's law. We consider fat embolism after ordinary fracture to be a rare condition, but like many other conditions, it doubtless occurs more often than is suspected. It was formerly thought that there was a negative pressure within bones, or that the trauma of fracture caused an increase of pressure within a bone to such an extent that fat was sucked or pressed into venous capillaries, and passed into the venous circulation. We do know that fat is found after some fractures in terminal arterioles of the lungs, kidneys and brain, and the symptoms are supposed to be caused by a mechanical plugging of the capillaries in the lungs, which induce dyspnea and cyanosis, or to those in the cerebral capillaries, which cause aseptic infarction of brain tissue, with subsequent necrosis accompanied by convulsions and death. Schultze and Behan[1] performed the experiment of opening dogs' bones and connecting them with a manometer. They obtained a negative pressure of about 20 mm. and believed that this negative pressure had much to do with fat embolism after fracture. Rothmann[2] repeated these experiments, taking four middle-sized dogs. He trephined the tibia, inserted a threaded metal tube into the opening and lined the tube lumen with paraffin to avoid clotting. He was unable to demonstrate any negative pressure, but obtained a very slight positive pressure in every case. He concludes consequently that absorption on account of negative pressure within bones is impossible.

LeConte and Gauss have made an interesting study of 14 cases of fat embolism in connection with supposed delirium tremens and pneumonia following fracture.[3] One of these cases, Dr. Graham's at the Presbyterian Hospital, was clinically diagnosed. On the second day the patient developed pulmonary, cerebral, and cardiac symptoms of fat embolism and had punctate hemorrhages in the skin. Exitus ensued on the fourth day. The tissues were prepared according to the method of Bolton and Smith.[4] Fifty sections from each piece of tissue were examined, and five sections containing average amounts of fat were used to compare with thirteen from other fracture cases at the Cook County Hospital, which terminated fatally with delirium and high temperature. The amount of fat in ten fields of a section of a similar organ was compared with ten fields of Dr. Graham's patient, whose tissues were used as a standard, and the percentages of several organs were averaged. Quantities of fat emboli from 5 per cent. to 45 per cent. were found in these 13 cases. Heart, lung, kidney and liver sections were used in the computation.

I quote from the report: "In all instances, the lung tissue where

[1] Müchen. med. Wchnschr., 1912, No. 52.
[2] München. med. Wchnschr., 1913, p. 1664.
[3] Tr. Chicago Pathol. Soc., April, 1915.
[4] Centralbl. f. allg. Path. u. path. Anat., 1903, xiv, 620.

examined contained fat emboli, which ranged in size from 5μ to 225μ in diameter; also, there was active hyperemia in all, and microscopic hemorrhages in half. In all but one, the heart muscle contained vessels with fat emboli in them from 5μ to 40μ in diameter; also, there was hyperemia, hemorrhages in twelve, and fatty degeneration in six. The kidneys from all fourteen bodies contained fat emboli from 5μ to 80μ in diameter, and there was hyperemia in all, hemorrhages in ten, and fatty degeneration in thirteen. In the liver of six bodies, emboli were found, 30μ in diameter; in twelve there was engorgement of the vessels and fatty infiltration. In seven this accumulation of fat in the liver cells was marked, covering one-half to seven-eighths of the microscopic fields. Fat emboli were also found in the brain, suprarenal glands, gastric mucosa, testis, and spleen in several instances. Edema of the brain was diagnosed grossly in seven, and fat droplets were detected in the blood at the time of the postmortem examination in seven."

TABLE 1.—ANATOMICAL CHANGES

Case No.	Quantity estimated compared to No. 1.	Lung.			Heart.					Kidney.				Liver.		
		Size of fat emboli, microns.	Act. hyperemia	Hemorrhages.	Size of fat emboli, microns.	Act. hyperemia	Hemorrhages.	Fragmentation.	Fatty degeneration.	Size of fat emboli, microns.	Act. hyperemia	Hemorrhages.	Fatty degeneration.	Size of fat emboli, microns.	Fatty infilt.	Engorgement
1	100%	10- 50	+	+	10-40	+	+	-	+	20-80	+	+	-	20-30	-	+
2	35%	15- 35	+	+	*	..	..	..	..	10-75	+	+	-	5-10	+	+
3	35%	15- 60	+	+	-	+	+	-	-	5-35	+	+	+	30-50	+	-
4	35%	15- 60	+	+	10-15	+	+	+	-	15-40	+	-	+	5-15	+	+
5	45%	20-225	+	-	20-30	+	+	-	+	20-60	+	-	+	-	+	-
6	40%	10- 90	+	-	5-15	+	+	+	-	10-30	+	+	+	-	+	+
7	10%	10- 35	+	+	*	..	..	..	..	5-40	+	-	+	*	....	..
8	15%	10- 25	+	-	5-20	+	+	-	-	5-40	+	+	+	-	++	+
9	25%	10- 35	+	-	5-15	+	+	+	-	10-60	+	-	+	10-15	++	+
10	25%	*	..	..	5-15	+	+	-	+	10-60	+	+	+	10-15	++	+
11	20%	5- 80	+	-	10-20	+	+	+	+	5-60	+	+	+	-	++	+
12	10%	20-100	+	+	10-20	+	-	-	+	40-60	+	+	-	-	++	+
13	25%	10- 60	+	-	15-35	+	+	-	+	15-55	+	+	+	-	++	+
14	5%	15- 50	+	-	*	..	..	..	..	10-45	+	+	++	-	++	+

Cerebral fat emboli in 1, 3, 4, 11. (Others not examined microscopically.)
Edema of the brain in 1, 2, 3, 5, 8, 11, 14.
Fat droplets in the blood in 1, 6, 7, 8, 9, 11.
Petechial hemorrhages in the skin or organs in 1, 4, 6, 7, 8, 10, 11, 12, 13.
* Not examined.

The symptoms and diagnosis depend on the character of the embolism. Some authors divide fat embolism into two forms, the respiratory and cerebral. In the respiratory form the patient develops symptoms of restlessness, dyspnea or Cheyne-Stokes respiration, cyanosis, and vomiting within a few hours to two days after fracture or orthopedic operation. This condition may follow a simple fracture, such as a fracture of both bones of the leg, in an apparently healthy man. Râles appear in the chest, a blood-stained, frothy mucus comes from the mouth, and there is fever. There is a quick progressive course with unconsciousness and fatal termination. The cerebral form may come on during the course of orthopedic manipulation, and the patient may

never come out of the anesthetic. Gaugele[1] believes that many of these deaths are attributed to the anesthesia when they are really fat embolism of the cerebral type. The cerebral form may also come on soon after bone reduction or fracture. There are great restlessness, muscular twitchings, convulsions, and paralysis. A rise in temperature to 102° has been observed. Nearly all cases show marked dyspnea. The clinical table of the cases investigated by LeConte and Gauss follows. Some cases undoubtedly recover spontaneously;

TABLE 2.—CLINICAL OBSERVATIONS.

Case No.	Sex and age.	No. days patient lived.	Bone fractured.	Temperature.		Symptoms. Cerebral.				Symptoms. Respiratory.				Symptoms. Cardiac			Urine and feces involuntaries.
				Lowest	Highest.	Restlessness.	Delirium.	Restrained.	Coma.	Dyspnea.	Rales.	Rate.	Other symptoms.	Weak pulse.	Cyanosis.	Rate.	
1	M. 35	4	Tib. fib.	97.8	106.2	+	–	–	+	+	+	64	C-S	+	+	164	+
2	M. 64	5	Humerus	98.0	105.4	+	–	–	+	+	–	60	A-H	+	–	120	+
3	M. 52	5	Pelvis	98.8	105.0	+	+	+	+	+	–	44	Co	+	+	130	+
4	M. 59	3	Humerus	?	?	+	+	+	–	+	–	?	A-H	+	–	142	–
5	M. 42	6	Tib. fib.	97.0	103.0	+	+	+	+	+	–	40	....	+	–	150	+
6	M. 52	3	Humerus	98.0	104.2	+	+	–	–	+	–	30	....	+	–	128	+
7	M. 45	5	Femur	98.4	107.4	+	+	+	+	+	–	42	A-H	+	+	140	+
8	M. 51	6	Tib. fib.	98.0	105.6	+	+	+	+	+	+	68	A-H	+	–	120	+
9	M. 58	14	Femur	98.0	104.0	+	+	–	+	+	+	60	Co	+	–	136	+
10	M. 62	2	Femur	101.0	106.0	+	+	+	+	+	+	72	....	+	+	134	+
11	M. 56	6	Tib. fib.	98.0	106.0	+	+	+	+	+	–	60	C-S	+	–	156	+
12	F. 35	7	Tib. fib.	98.6	105.2	+	+	+	–	+	–	34	....	+	–	140	–
13	M. 39	5	Calcaneus	99.6	108.2	+	+	+	+	+	–	60	....	+	–	140	+
14	F. 90	17	Femur	96.9	101.4	+	+	+	+	+	+	48	....	+	–	112	+

Diagnosis of delirium tremens in 4, 6, 8, 12.
Diagnosis of delirium tremens and lobar pneumonia in 7, 10.
Diagnosis of delirium tremens and hypostatic pneumonia in 9, 11.
C-S = Cheyne-Stokes, A-H = air hunger, Co = cough.

others are considered to be in a condition of delirium tremens, or to be suffering from embolism of a septic character. Pure pulmonary symptoms are rare, and probably in accordance with LeConte's findings the fat embolism is the cause of all symptoms and death. In only 1 of the 14 cases was there found any evidence of pneumonia. That was a slight bronchopneumonia. As prophylactic treatment, reduction by rough manipulations should be avoided, or an intravenous injection of normal salt solution may be given immediately after the manipulations. After the onset of symptoms the fracture site must be immobilized thoroughly to prevent motion of fragments, and heart stimulants and strychnine are given hypodermically. The diagnosis is often confused with shock, hemorrhage, and postanæsthetic, pulmonary edema. Cotton gives Dennis's rule as a means of differentiation. Shock three hours, fat embolism three days, pulmonary embolism three weeks. In the Cook County Hospital in the series of

[1] Ztschr. f. orthop. Chir., 1914, xxxiv, Heft 1–2.

10,702 fractures fat embolism was diagnosed four times clinically. LeConte and Gauss call attention to the medicolegal importance of fat embolism and the difficulty that exists in civil and criminal courts of proving that death was not caused solely by delirium tremens.

3. *Delirium Tremens.*—In city hospitals, delirium tremens follows traumata of all kinds, particularly fracture, which confines the patient to bed and takes away the customary amount of alcohol. In 10,702 cases of fracture this complication was present 179 times. Some attacks lead to a fatal ending. If the patient is very unruly he may be strapped and the injured limb protected by a suitable cast. Fat embolism must be differentiated. There is a history of alcoholic habit with sudden deprivation of the alcohol. After an onset characterized by nervousness and restlessness, hand tremor, loss of appetite and sleeplessness, the condition passes into a delirium of muttering type, not often very violent. I saw some years ago, following an open fracture of the forearm, one case of tetanus with onset on the eighth day. The condition simulated an alcoholic delirium, because the twitching and muscle spasms of the arms with general nervousness were the most prominent symptoms. Trismus did not appear until much later. Known alcoholics should not be deprived of their drink after fracture. The amount taken can be gradually cut off. The bowels should be opened by a cathartic and as much diet given as the patient will take. After the onset the fractured limb is protected with extra dressings, and the usual treatment of sedatives, ergot, etc., is instituted to induce sleep and quiet.

4. *Tetanus.*—Tetanus is unknown after closed fracture. Open fracture of any bone is liable to this infection, if street dirt is carried into the wound. Open fractures in steel mills or factories where the dust and dirt are reasonably sterile do not often give tetanic infections Of the 10,702 fracture cases reviewed 3 had tetanus. Prophylactic treatment consists in ample drainage of the wound with a cutting away of crushed and soiled edges. Immediate injection of 1500 units of antitoxin is also indicated when there is any suspicion of the infection. When the disease is once inaugurated the treatment consists in intraspinal and intravenous injection of large amounts of antitoxin, according to the method worked out by Irons at the Cook County Hospital.

5. *Shock and Death.*—Shock and death are the most important complications. In the series of 10,702 cases, there were 9768 closed fractures. 749 of these resulted in death; 126 resulted in shock, which became so pronounced that treatment was primarily directed to it. These cases recovered. There were 379 open fractures in the series, 34 of which resulted fatally and 1 had serious shock without death. Many factors such as age, the patient's general health, other injuries, hemorrhage, and other complications must be considered in the sifting of the total figures.

6. *General Sepsis.*—General sepsis occurs in both open and closed fractures, which have a gangrene of the tissues with infection about

the fracture site. The source of infection is probably the gas bacillus or the organism of a malignant gangrene. Locally the tissues become necrotic and foul-smelling and slough. There is little discharge of pus, but the wound oozes a watery, bloody discharge. Emphysema from the bacteriological production of gas is often seen.

Treatment is early amputation. The most copious drainage fails to afford relief, and as the symptoms of general sepsis from absorption begin to appear inside of forty-eight hours amputation may not be successful. There is high fever, restlessness, and delirium with a fast and failing pulse. If the shock of amputation is added to this condition, the prognosis is very bad. Patients in good health may survive, others hold out ten or twelve days, and those of alcoholic habit or in poor general condition die within the first week after accident.

Late General Complication.—1. *Postural and Weight-bearing Changes.*—Lower limb fractures which result in malunion or union which does not perfectly restore the weight-bearing axis, lead to late general complications which involve the gait and posture. If there is lateral or anteroposterior deviation of the bone axis, there results an erroneous deflection of the body weight. There is cross strain exerted at the fracture site and strain on the near-by joints. Shortening of the affected limb may also be present, and when function is resumed the patient walks with a dip toward the affected side. This causes pelvis tipping and lateral curvature of the spine. Slight degrees of malunion are often thus compensated, and the bone itself takes on a corrective growth of realignment in accordance with the idea expressed in Wolff's law. The same statement applies to upper extremity fractures, inasmuch as the function of the limb is disturbed. These complications must be guarded against by the obtaining of perfect reductions and the employment of correcting splints and supports after use of the part is started.

2. *Neurasthenical Conditions.*—Neurasthenical conditions are commonly seen in both hospital and private practice following fracture. These conditions are sometimes found in those who seek damages for accidents or have claims under compensation acts. Sometimes patients get into a marked condition of mental depression; they have no desire to aid themselves or return to occupation, and they drift into hospitalism. Others, and many men are among them, will nurse an unimportant fracture for months or years, ascertaining all sorts of remote complications in order to obtain damages or awards under compensation laws. I have recently been interested in a case of fractured clavicle with no complications, following which the injured man has done no real work for five years, although the result is above the average. Pecuniary settlement often sets these people with simulated neurasthenical conditions right, and the mental recovery follows very quickly.

Local Complications.—**Early Local Complications.**—Local complications are in reality local conditions affecting tissues other than the bone at a fracture site. Many cases escape untoward consequences,

and we are likely to overlook the local pathology of the soft parts except in those cases where its exaggeration attracts attention. The muscles and fascial sheaths lie nearest the bone and are injured by the trauma causing the fracture, by penetration of bone fragments or pressure from within the limb through hemorrhage and extravasation. The muscle may be torn completely with much hemorrhage. Fascia is tougher and yields less, but is frequently ruptured. The repair is by connective tissue which may become adherent to surrounding parts. (See Late Local Complications.) There is always swelling, soreness, and edema. Hemorrhage may burrow for a long distance beneath intact fascial sheaths and cause pressure complication.

Volkmann's ischemic contraction is the term applied to a type of contraction of the muscles and the changes in the soft parts distal to the point of fracture.

Causes.—Volkmann's original description in 1875 attributed the contraction to tight bandaging, which led to an ischemia of the muscles from pressure. There was no primary nerve pressure injury. We believe now that the pressure may come not only from tight bandaging, splints, or casts, but also from pressure within the extremity caused by the extravasation of blood beneath resisting fascial envelopes. There are cases on record following fracture in which no splint or bandage of any kind was applied. Murphy,[1] Collinson,[2] and Jones[3] have seen cases. Bardenheuer[4] states that 8 per cent. of the cases follow fractures to which no dressing or attempts at reduction have been applied. Jones reported having treated 24 cases up to 1908. 19 of these were associated with fracture, while 6 cases had not sustained fracture. Of these 6, 2 were arms which had been crushed by wheels, 1 had been subjected to pad pressure on the forearm for twenty-four hours to stop bleeding from the palmar arch, and 1 was a child's arm from which the elastic tourniquet had not been removed after an operation for webbed fingers. A few authors have attributed the contraction to primary nerve involvement, or a localized ischemia involving certain bloodvessels or muscle groups. Exposure to extreme cold has also been considered a cause.

Pathology of Volkmann's Contraction.—Volkmann and Bardenheuer were of the opinion that the condition was caused by a necrobiosis of the muscle cells caused by interference with circulation of blood in the part. Bardenheuer thought that the muscle cells were poisoned by the metabolic products in the unchanged blood of the part and the necrobiosis was really death from auto-intoxication. The more recent investigators believe that the process is a pressure ischemic myositis caused by the pressure of hemorrhage within the tissues, which is often aided by external compressing bandages or casts. There develops a myositis which leads to contracture of the muscle as a whole. The muscle body is atrophied and becomes a grayish

[1] Jour. Am. Med. Assn., lviii, No. 15, 1249.
[2] Ibid., p. 1255.
[3] Am. Jour. Orthop. Surg., 1908.
[4] Deutsch. Ztschr. f. Chir., 1910, cviii, 44.

color, like a mass of connective tissue with scant blood supply. Fractures about the elbow are the most frequent cause. Thirteen of the 19 cases Jones reported as connected with fracture had malunion, and 3 had excess callus and good alignment. There are a few cases occurring after fractures about the knee. The damage to the muscle cells is done within the first seventy hours, but the muscular contraction and flexion of the fingers come on later. The retraction of the fingers may not start to manifest itself until three or four weeks, when the cast or dressing is removed. In some cases in which no bandage or splint was used, the contraction has started on the third or fourth day after injury. In three months the fingers become fixed in their flexed position, and further changes are not caused by muscle shortening, but are probably the result of complete exhaustion of the extensor muscles, and an increase in the length of the bones. The nerves are rarely involved, and it is believed that nerve injury is not essential to the muscle contracture. The reported cases of cure following operation or Jones's extension method corroborate the supposition that the nerves remain intact in most cases. Nerve injury may be caused by trauma or by callus pressure, but rarely from pressure of the infiltration or the muscle contraction.

Symptoms.—The early evidence of the pressure ischemia in the muscles is swelling and stiffening in the hand and fingers, accompanied in some instances by cyanosis and coldness. There is always continuous and intense pain. The patient complains, and the splint may be removed. When it is not, the swelling and cyanosis in the hand and forearm increase, and the pain gradually subsides. No attention may be paid to the pain which is considered a necessary symptom of the fracture, but the changes in the muscle occur very rapidly and at the first evidence of swelling and edema with cyanosis the dressing should be loosened. Later symptoms consist in the flexion deformity of the fingers and hand. There is great atrophy, the hand and fingers are in flexion. The extremity is cold and the skin glazed and blue. There are contractions of the capsular ligaments of the joints involved. The fingers are flexed into the palm, and when an effort is made to extend the wrist the finger-nails bite into the palm. If the wrist is further flexed, the fingers may be extended a little, but in cases of long standing the capsular ligament about the joints become stiffened and contracted. The elbow is flexed, and the forearm muscles are atrophied and feel like a hard mass moulded together. If there has been concomitant nerve injury, there will be an electrical reaction of degeneration in the muscles.

Treatment.—Prophylactic treatment consists in avoidance of constricting bandages or splints about fractures of any kind, particularly those involving the lower end of the humerus and the forearm. Splints should not be applied to force a reduction of a fracture. The fracture must first be reduced and external splinting must serve merely as a mechanical fixation in the position gained. It is also wise to allow the first traumatic swelling to have full freedom. No tight bandages

should be applied, and the limb must be put at rest in a comfortable position. This rule also means that fresh fractures about the elbow region should not be treated by an immediate position of extreme flexion. When the arm appears cold, swollen, and cyanotic, and persists so in spite of removal of all dressing, the rigid fascia on the ulnar side of the forearm should be split for several inches subcutaneously to relieve pressure of the hemorrhage within the tissues. At the elbow the antecubital region may also be opened subcutaneously. These operations can be performed through a small skin opening with a tenotome. Reduction and permanent dressing of the arm are postponed until swelling has subsided, that is, for a week or ten days.

Treatment is non-operative and operative. The non-operative aims to produce and maintain extension of the fingers and restore forearm function by massage and electricity. This is seldom successful in any degree. Jones's method, described in 1908,[1] is as follows: fine zinc or iron strips are cut which fit the patient's extended fingers. While an assistant flexes the wrist, the fingers relax enough to permit each finger to be splinted by one of the metal strips, which are bound on. The patient attempts to extend the hand, and in a few days a splint is applied over the first splints and extending from finger tips to wrist, with some extension gained gradually. Further extension efforts are made by the patient, and later splints are applied as high as the elbow, so that by degrees the wrist becomes fully extended. When the hand becomes hyperextended, its circulation improves and the different tissues take on a more normal appearance. Jones thinks that every structure is stretched in the order of its tension, and that the method should be preferred to open operation.

Operative methods have been devised and used to shorten the forearm bones by removing a section of each and wiring or plating the fragments together. When this is done aseptically with bony union the results are good. Efforts to cut the muscles subcutaneously produce no lasting benefit, because cicatricial contraction follows with greater shortening than ever. The best open operation is a tenoplasty to lengthen all the flexor tendons above the wrist. Murphy gives the principles of this treatment as follows: There is a correction of the tendon deformity by true elongation, not mere division. The muscles groups must be balanced so that there is no tendency to subsequent contraction. Sufficient transverse division of the joint capsule at the wrist and the forearm fascia must be made at the operation to permit full motion of the hand and wrist to a position of hyperextension, where it is maintained during the healing.

The adjacent tendons are not divided on the same plane, and as each one is divided it is sewn, but the sutures are clamped and not tied until all tendons are free. Elongation must be sufficient to permit full extension of the wrist. The after-treatment consists in gentle

[1] Loc. cit.

massage and active attempts at use by the patient, satisfactory final results following in most cases after many months.

Nerve Complications.—Early nerve complications are rare. In arm and leg fractures an effort should be made to ascertain at the first examination whether the important nerves have been injured. In fractures of the spine, or clavicle, or about the shoulder region, the branches of the brachial plexus may suffer injury or be totally avulsed from the spinal foramina. The commonest nerve injury is that of the musculospiral nerve in fractures of the humerus—which see. About the elbow the ulnar and median nerves may be injured, and near the knee the external peroneal nerve may likewise be damaged.

Bloodvessels.—In closed fracture arteries and veins are seldom seriously injured. Their shape protects them, and if they are torn across the retention of the blood within the tissues prevents extensive hemorrhage. Vessel coats may be lacerated and weakened without complete rupture at the time of fracture. Subsequent manipulation or movement of the part may complete the tear, and a secondary hemorrhage will result. Traumatic aneurism may also develop after a partial injury and slowly proceed during the course of the bone repair. Tearing of the lymphatic vessels and their closure may lead to prolonged edema in a limb.

A few fractures are commonly associated with bloodvessel destruction and hemorrhage. Rupture of the middle meningeal artery in skull fractures is one of these. Fractures and dislocations of the head and neck of the humerus are likely to wound the axillary vessels, and the subclavian in clavicular fractures, the popliteal in lower femoral fractures, and the tibial or nutrient arteries in the leg may also be involved. Open fractures, especially those caused by direct violence, cause bloodvessel injury. Laceration of muscle bellies opens a great number of small bleeding-points, and frequently vessels of considerable size are ruptured. The character of crushing injuries protects against severe hemorrhage in many cases, because the bloodvessels are compressed or retracted within the muscle masses and the intima rolls in to close the lumen. I have seen several crushing leg and arm injuries with almost total severance, which bled but little. Less severe injuries which have an open wound may cause bleeding from one point which is exhausting. There has not been enough trauma to close the vessel. Bleeding is more serious from torn veins than from arteries as a rule, and may continue for hours. Legs with varicose veins are dangerous in this connection.

The symptoms of hemorrhage within a limb are pain and increased local swelling, which usually becomes pulsating and interferes with circulation distal to the fracture site. Compression at this point by bandage is not indicated. Rest, elevation, and the application of cold may alleviate the trouble, but if the condition persists and nutrition of the limb is threatened, open operation to stop the hemorrhage and repair the fracture is indicated. Rupture of a vein causes symptoms appearing more slowly and is difficult to recognize.

Gangrene is a rare early complication. The tissues locally may necrose from pressure and interrupted blood supply. Local patches of tissues and skin become blackened and slough even in closed fracture; ulceration may proceed, which results in a late opening of the fracture to the air. The prognosis of superficial patches of dry gangrene is good. Granulation beneath accompanies the separation on the surface, and by the time the patch is freed the area beneath it is on a road to recovery. Secondary infection beneath a patch spreads locally into the fascial and muscle planes and causes a foul-smelling, watery discharge which clears up under sufficient drainage.

Gangrene of a whole or distal portion of an extremity is rare in closed fracture. It may occur in elderly patients caused by rupture of the important artery, or by pressure from hemorrhage within a limb on all of its blood supply. Incisions into the skin and fascia for drainage to relieve this pressure are practically never necessary. Some of the most extensive and prolonged infections of bone and soft parts I have ever seen have followed incision to relieve pressure which appeared to threaten distal circulation. Elevation, hot or cold applications, massage, and other external maneuvers must be employed, or the fracture must be opened under the rigid asepsis of operative technique and tightly closed after reduction.

The inception of extremity gangrene is manifested by a change of color of the skin and the appearance of blebs, which are often bloody and dark stained. The limb becomes cold, and sensation decreases in it. All constricting bandages or adhesive dressing should be removed at once and heat applied. In the 10,702 fracture cases reviewed at the Cook County Hospital, there were but 5 cases of gangrene in closed fracture.

Thrombosis originating from trauma or infection at a fracture site may extend the length of a limb and result in moist gangrene where a vein above is involved or a late dry gangrene, when the arteries are concerned. Embolism may be an early complication if manipulation dislodges a portion of a thrombus.

The treatment of open fracture and the indications for amputation for threatened or established gangrene are considered in the chapter on Treatment. Bloodvessel anastomoses and plastic repair in a fresh fracture site are practically never a success.

Late Local Complications.—1. CALLUS COMPLICATIONS.—(*a*) *Excessive and Painful Callus.*—Excessive callus is the result of wide displacement of fragments, irritation of motion, the presence of small necrotic fragments and a hyperactivity of the osteogenetic cells peculiar to some individuals. Fragments which are widely separated need a large callus to cement their union. Small fragments which become necrotic and lie in the path of the main callus repair are overgrown by the new bone formation and remain as an irritation until they have been absorbed or revascularized and made over into new bone. This process is similar to the absorption of the necrotic area on the edge of the fracture plane, which precedes repair in all complete frac-

tures. It is not like sequestrum formation following infection, in which the most damaged part of the bone is exfoliated after its death. Some persons tend to develop a large callus for no explicable reason. Motions of premature use, or massage and passive motion forced on fractures near joints, are likely to lead to excessive callus. This callus may not appear large to external examination, but it may lie at just such a point that it interferes seriously with joint motion, restricting it so that there is functional loss. Excessive callus is also found in open fractures which have become infected. Large masses of bone with sinuses and granulating suppurative patches may surround a fracture site. Parosteal bone formation, which may be called excessive or unnecessary callus, is considered under the late complications involving muscle and fascia.

Excessive callus frequently diminishes in size in six to twelve months, as use of the part is insisted upon. The enlarged bone shrinks down to conform with the physiological demands. In some cases, however, with malunion the excessive callus persists and remains to interfere permanently with circulation or to cause pressure effects on the nerves and skin. In these cases the callus is removed by operation. External applications, massage, and the Roentgen rays have little power to promote absorption. The mass can be chiseled off and the contour of the bone restored to normal. Near joints, if the articular surface is encroached upon, a modified arthroplasty must be done. After the excessive bone is removed, the denuded surfaces are covered with pedunculated flaps of fat or fascia from nearby areas. In this way, further regeneration of bone is provided against and a movable joint is insured. The elbow, shoulder, and hip are all adapted to this type of operation, and the results are satisfactory.

Painful callus is often an excessive callus. A large mass may press on nerve trunks, it may include some terminal nerve filaments in its body, or by attachment to muscles, tendons, and interference with joint action, it may produce pain. On the other hand, painful callus may not be of unusual size. When the pain begins early in the healing of the fracture, it is probably on account of the inclusion or compression of a nerve, unless there has been an open fracture with infection. The pain is usually continuous and after several weeks subsides, as the nerve is obliterated by the pressure. Neuritis caused by systemic conditions or trauma received at the time of fracture must be differentiated before operation is advised for relief. Attention must be directed to focal infections in all parts of the body to rule out metastatic infections of nerve trunks. The teeth, cranial sinuses, urethra, prostate, gall-bladder, appendix and bowel must be investigated in regard to infectious condition. If local applications are valueless to relieve a bruised nerve, and infectious neuritis is ruled out, operation on the callus must be undertaken to alleviate the pain. After excessive use or weather changes, callus may be sensitive for many months or years succeeding fracture. The knowledge we obtain of the arthritides, however, seems to indicate that many of these

prolonged and painful conditions in the callus are comparable to the low-grade infections which cause the slow progressive and painful changes in osteo-arthritis.

Painful callus originating late in the healing process is nearly always caused by infection and osteomyelitis. Most of these cases have followed open fracture and operative repair of closed fractures. The pain may not be noticeable for some weeks. After the patient begins to walk or to use the limb it becomes evident and is worse at night. Eventually there is an appreciable tenderness to tapping over the bone. There may be some swelling, and sinuses will appear through the skin. Painful callus or pain in a fracture site arising late should always be subjected to roentgenogram. Small areas of necrotic and infected bone are detected by their dark shadows. Rest in a plaster encasement, intermittent periods of hyperemia by means of a constrictor, and general hygienic measures may bring about absorption of these spots with relief of pain. When they persist, open operation with curetting and drainage is indicated.

(*b*) *Weak Callus.*—Weak callus becomes apparent after a normal course of bone repair. It is not comparable to delayed union or non-union, because both clinical and Roentgen-ray examination may show a satisfactory osseous consolidation about the fragments. Callus may appear normal and yet become weak and inefficient under three conditions:

1. Premature use of fractured part and its subjection to great strain before complete calcification has taken place.
2. A secondary weakness caused by systemic conditions.
3. Local conditions—pressure of bandages and peculiarities of the type of fracture.

Premature use of fracture before complete consolidation causes irritation and leads to an increase in the callus reaction. If use is persisted in, movement may develop, and the callus bends to give under the stress. An absorptive reaction may be set up. An ordinary example of this type of weak callus is found in the ankle after fracture of the external malleolus. Patients are permitted to start walking without support under the foot arch in the fourth or fifth week. Bone union is generally present, but as the body weight is applied on the fresh union, the callus becomes inadequate to hold under the lateral strain and begins to give a little. The result is that although the patient was discharged after four weeks with a straight ankle and foot in proper weight-bearing line, he returns in four more weeks with a pronated painful foot, and a weak, yielding callus in the site of the fibular fracture. This same mechanism may cause giving in any fracture. (See picture of plated fracture of femur walked on too soon.)

The second cause of weak callus is systemic syphilis, scurvy, lactation, faulty calcium metabolism and general infections which lead to absorption of callus and its weakness. The process may be slow, and an angular deformity from giving of the bone results after some

time. In some conditions if slight trauma is added, refracture may occur through the original site (Fig. 18). This refracture occurs in some cases of internal splint fixation which are clean, especially in those repaired by intramedullary bone grafts. It is a question whether there is a systemic condition to blame or whether the absorptive process in the transplant has a broader local effect and weakens the callus so that trauma easily effects refracture.

Local conditions at the fracture site also have influence on the callus strength. Fractures of the shaft of the femur in which a triangular piece of the heavy compacta is removed or broken off are likely to

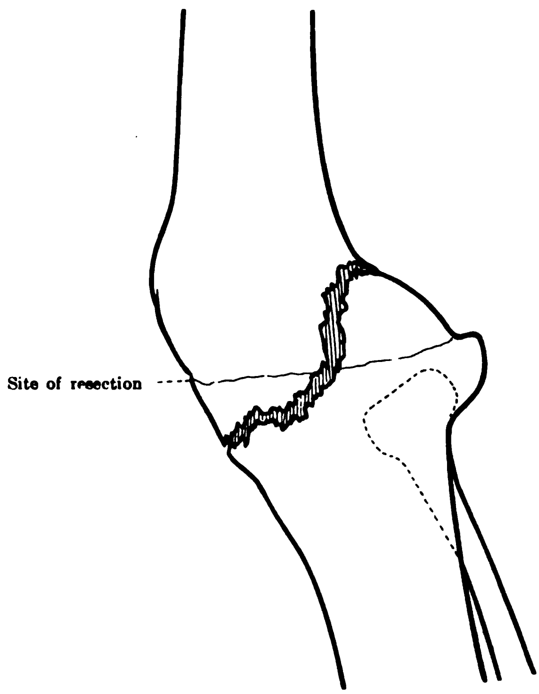

FIG. 18.—Fracture through a united resection of the knee. Note that the plane of fracture has not followed the old joint line which has firmly united, but has taken a new course as if there were one long bone from hip to ankle.

have a weak callus. They should be granted a long period of rest that the callus may become thoroughly calcified and contracted so that the new lamellæ are capable of taking on the strain of weight bearing. The application of tight bandages or other interference with free circulation and injudicious use of the muscles about the fracture site in a long bone may cause weakening of the callus.

(c) *Delayed Union.*—(d) *Non-union.*—These two subjects are considered together not because they are identical, but because delayed union sometimes merges into non-union and the terms have been loosely applied in practice. Delayed union means that the ordi-

nary time required for the establishment of bony union in fracture of a long bone is exceeded. Each fracture must be judged by a number of similar fractures in the corresponding bone with more or less the same type of displacement. After an average time for union is determined upon, other factors then come into consideration. The patient's age, general condition, surroundings, and the type of dressing may influence the time needed for repair. The individual osteogenetic power also has a bearing on the rapidity.

An example may be taken of a fracture of the shaft of a long bone. In the course of an average repair period the surgeon removes the permanent dressing to inspect the limb. He is surprised to find when tests are made, more or less freedom of motion at the fracture site. Often instead of replacing the dressing to permit a longer period of immobilization, he begins to worry about non-union, and the limb is inspected daily and all possible expedients are called into play to promote union. The slight motion and irritation of the fragment ends may be beneficial. If union does not follow very shortly the fracture is put into the class of non-union long before its time. Probably every surgeon of experience has seen fractures of the shaft of the tibia or femur which took six months to become firmly united. Delayed union is a fairly frequent occurrence; fibrous union, pseudarthrosis, and non-union or failure of union are rare.

Fibrous union is a term which signifies that the bond which has developed between two fragments is in a connective-tissue stage; that is, the fibrous tissue proliferation from the periosteum or surrounding parts predominates, and the outgrowth of bony lamellæ has been checked or partly inhibited. This fibrous band, though strong, is not solid, and permits motion and causes functional loss. In the patella and sometimes in the femoral neck we anticipate such a union. In the shafts of long bones, a fibrous union, given time and aided by efforts to promote calcification, will often terminate after months in a solid, bony junction.

Pseudarthrosis indicates the formation of a false joint between the connected fragment ends. This false joint has a heavy fibrous outer wall, which simulates a capsular ligament and a synovial-like surface within. Non-union or failure of union is a term which means absence of bony growth between fragments, so that this term is the broadest and covers both fibrous union and pseudarthrosis, but also implies that the union present will never become bony if left to itself. Failure of union is a term which should only be applied to the exceptional cases which show lack of bony union of months' standing and which are hopelessly permanent.

In the total series of 10,702 fractures reviewed at the Cook County Hospital, there were 123 cases of ununited fracture. Some of these cases were not true failures of union, but represented the class of delayed union, and the older history sheets do not warrant an exact discrimination. The proportion of non-unions after fracture probably is less than 0.6 per cent. The most frequent site of non-union is in the

lower third of the shaft of the humerus, if we consider long bones only. The next most frequent site is the lower third of the tibia; next the upper third of the humerus, and the lower third of the forearm, the upper third of the leg and finally the femur follow in order. Murphy in one statement,[1] puts fracture of the lower third of the tibia in second place, and in another place[2] he puts the tibia in fourth place on the list. Open fractures are more frequently followed by non-union than closed, especially those which have been treated primarily by internal splints. Sprain fractures, separation of small pieces near the articular surfaces of bone, and fractures of the femoral neck, are not included in this enumeration. Hawley[3] reports 53 cases of ununited fracture in a total of 1200 cases. His cases had a distribution different from what most authors have recorded, because none involved the humerus, ulna, clavicle or fibula. With the neck of the femur excluded no ununited fracture involved the vascular ends of long bones, but the sites were shaft of the tibia 22, the femur 15, and the radius 10.

Cause of Non-union.—General causes attributed to the patient's systemic condition were formerly considered of the greatest importance. These were defective nutrition arising from tuberculosis and rickets, alcoholism, malignancy, pregnancy and lactation, defective innervation as in tabes, syphilis, and acute systemic infections. Most of these causes after close investigation have been laid aside; even alcoholism and syphilis are no longer seriously considered as primary causes of non-union. Hawley found non-union in only 1 out of 8 cases of fracture caused by carcinoma of bones. (See chapter on Bone.) The disturbance of the calcium equilibrium has some bearing. Defective innervations and tumor formations have been put in the class of pathological fracture where they belong. There remains for consideration the various local causes. The order of their importance is not easily established. Open fracture, and particularly open fracture which has been fixed by internal splints, comes first. (See paragraph on Pathology.) Murphy[4] reports 5 cases of ununited fracture, all of which were originally open and 2 of which were operated on for the application of internal splints. Of 4 cases which I have seen in the shafts of long bones in the last year, 1 had been repaired by a Lane plate, and all were open fractures except 1 in the tibia. Failure of approximation of the fragment ends, either on account of angulation and overriding, or the interposition of muscle and fascia, are other causes. Interference with blood supply, particularly destruction or thrombosis of the nutrient artery, is a much overlooked cause. Too perfect immobilization which results in an insufficient stimulation for callus production by slight movements has been advanced as an etiological factor. The only argument in favor of this factor is that some motion seems to stimulate bony consolidation in delayed union. Near joints we know that premature and painfully enforced

[1] Clinics, i, 192.
[2] Ibid., iii, 116.
[3] Jour. Am. Ortho. Assn., 1914, p. 245.
[4] Clinics, i–iii.

movements cause an excessive amount of callus which interferes with the joint function. Maltreatment by the application of cold, the admission of infection through artificial wounds, insufficient immobilization and protection, and too early use all have a bearing on non-union. Some fractures after firm union will become freely movable later. The callus absorbs by some disturbance of the calcium distribution, possibly influenced by systemic disease.

Pathology of Non-union.—In open fracture there is more or less bleeding and draining away of the blood-clot which is believed to act as a support for the capillary outgrowth from the bone ends along which the new bone is laid down. There is also in a large percentage of cases some infection. This infection may be of very low grade, but by its toxic and lytic effect it causes destruction of the delicate bone projections and promotes their absorption. There is likely to be greater traumatization of the parts in open than in closed fracture, so that the preliminary layer of necrosis on the fragment ends is thicker. There are also small isolated bone fragments and greater interference with blood supply. During the slow local absorption under the conditions of open fracture there is tendency for a greater development of fibrous tissue from the periosteum and the surrounding soft parts, and as this fibrous tissue ages it contracts and crowds in between the bone ends, shutting off a possibility of early normal bone union. Cysts or joint-like spaces may develop in this fibrous tissue stimulated by the friction of use before bone is formed. In some cases small collections of blood are thus encapsulated between fragments and through metaplasia of the cells lining the cavity containing the blood, a synovial-like surface develops and pseudarthrosis results. In open fractures of the humerus internal splints applied on the bone aggravate and prolong circulatory interference and favor infection. They are consequently a secondary cause of much consequence in failure of union.

Accurate approximation and anatomical reposition of fragments prevent failure of union, because they lessen the distance which the capillary growth and the bone deposition must cover. Overriding, angulation, interposition of muscle and fascia, which increase the difficulty of the bone regeneration across a space, favor the occurrence of non-unions. Clinically we find failure of union of two types, one which presents a fair approximation of fragments with a fibrous band between them, and a second type with either overriding or separation, which is true pseudarthrosis. In the first type, which is the commoner, the fragments may not be worn off or appear abnormal, except that the ossification process between them has stopped in its course at some point. There may be exostoses from the fragment ends sticking out into the fibrous tissue, or there may be soft callus along part of the fibrous bridge, but the repair is atypical. When a gap exists between fragments and pseudarthrosis is present, the fragment ends are generally eburnated and well rounded, the medullary plug being as hard as compact bone.

The character of the blood supply is difficult to demonstrate in ununited fracture. The influence of a lack of good supply which may have existed at the time of fracture cannot be demonstrated after the condition of non-union exists. Studies of osteogenesis, however, show the character of capillary regeneration in the formation of new bone, and the observation of frequent non-union of the tibia *alone* in fracture of both bones of the leg calls attention to the question of interference with blood supply. The two bones lie side by side, subject to similar systemic conditions. One unites, the other does not. If the local conditions of tissue laceration and type of fracture are the same, as they must be in most cases, one must search for vascular difference to explain the non-union. One fragment of the tibia may be cut off from a vascular supply, and the layer of necrotic bone on the fragment surface is not promptly absorbed and revascularized. The local increase of regenerative powers is diminished, there is not enough force to the bone-growing surface, and this is overcome by connective-tissue regeneration from the periosteum or from surrounding tissues which have better and independent blood supply. The periosteum acts as a protector to bone capillaries and holds back the flood of young connective-tissue cells from the soft parts. When the periosteum is completely torn apart, these cells are free to wander in, and their growth crowds back the slower bone.

The effect of nerve influences of a trophic character is vaguely understood. It is clinically established that motor and sensory paralysis of a limb has little effect on the healing of a fractured bone in it, but trophic lesions do in some cases cause non-union.

Symptoms of non-union follow the line of those of delayed union, the latter merging into failure of union. There is abnormal motility at the fracture site after the surgeon expects a bony healing in a normal course of events. This period cannot be stated in specific time for any bone, and all cases which have a fair reduction and seem to offer no local evidence of interposition of muscle and fascia or necrotic bone fragments and which lack infection, should be considered as delayed union. Their treatment should continue as originally planned until one is positive that failure of union is present.

When the conditions of reduction are unfavorable on account of overriding and displacement, or when infection and other local conditions influence the progress of the union, agreement on the presence of non-union is easier to obtain. Young callus we know casts no shadow in the roentgenogram. If a fracture which has gone twice or three times the normal period required for union shows a clear line in the roentgenogram, excellent evidence is furnished of failure of callus formation. The mobility is the best evidence of all, because pain, swelling and crepitus may be entirely absent. The amount of motion varies. It is often difficult to demonstrate, particularly in the tibia, when the fibula helps maintain the rigidity of the leg. Functional disturbance does not vary directly with the mobility. Patients with an easily demonstrated point of mobility may be able to use a

leg or forearm quite satisfactorily and complain against further treatment when the non-union is discovered. Ultimately this function would be far below normal if deformity followed use and muscular pull (Figs. 19, 20, and 21). Some ununited fractures are painful. This type is often accompanied by an excess of callus production, and mechanical circulatory interference with constant pain after use is the symptom which leads to recognition of the condition. Sepsis must be differentiated, as must also tumor formation. If the humerus and femur are involved, especially the latter, function is much interfered with. (See illustrative cases in chapters on Fractures of the

Fig. 19.—Ununited fracture of humerus, nineteen years old. When he attempts to raise arm, upper fragment of humerus is pulled up normally, but on account of false joint in arm at site of non-union, the lower portion hangs down and cannot be elevated. Hand and forearm have good power and he can carry weights as shown.

Humerus and Femur.) In non-union of leg fracture the patient is often able to walk with a cane if the leg is strengthened by a metal or plaster splint.

Treatment of Non-union.—Mr. Robert Jones[1] says that ununited fracture is often the result of surgical impatience. There would be fewer cases if there were less operative work undertaken to apply internal splints to open fracture. Also, as previously stated, instances of delayed union should be given persistent attention directed along

[1] Brit. Med. Jour., December 7, 1912.

the line of the treatment originally planned until hope for any bony union is lost. Too frequent manipulation and inspections are harmful.

The chapter on Treatment deals with this subject, and it is simply necessary to recall the general line of treatment to be adopted with brief review of the many expedients which have been tried.

First of all it is unwise to use internal splints on open fracture. If there is infection in open fracture, that fact necessitates primary

Fig. 20

Fig. 21

Figs. 20 and 21.—Ununited fracture of humerus, nineteen years old. Note that he can make fist and completely extend the fingers and hand. He has to support the heavy muscular forearm at elbow in holding the arm in an extended position for this picture. No evidence of injury to any nerve of brachial plexus.

attention in the way of drainage, and though the limb is held in a suitable dressing to prevent deformity, the bone union is looked upon as secondary. Non-union existing in bones which have been fixed by wires, screws, nails, plates or other internal splints, must be studied by roentgenogram, and in most cases they pass into the operative class at once for removal of foreign bodies or the drainage of infection. Constitutional diseases are treated, if they are considered at fault.

Antispecific treatment in syphilis is indicated until enough clinical evidence is furnished to show the effect of syphilis on bone repair. Nourishing diet, hematinic tonics, and outdoor life must be used for stimulating general effects. I have never seen a case in which the use of glandular extracts such as thyroid had any effect. (See Local Non-operative Treatment.)

It is my practice to put every case of delayed union back into its original line of treatment, usually a plaster dressing of some character. In the leg a fairly heavy plaster encasement is used, and the patient is permitted to use crutches. Sometimes slight use of the foot is encouraged in order that irritative stimulation may be afforded to the bone. The value of this stimulation lies not so much in the local irritation at the fracture site as in the *strain put on the longitudinal axis of the bone*. This calls for a deposition of calcified material in accordance with Wolff's law, because the bone is responding to physiological demands.

Massage and local hyperemia by Bier's method of constriction or by baking are also used. The Thomas method of damming and percussion is performed by a heavy mallet, the ends of which are padded; the application of broad rubber tubes a few inches above and below the site of non-union supplies the hyperemia. Daily beating is performed with a splint applied in the intervals. This leads to many cures. Local treatment is also furnished by cupping or by the application of a plaster encasement in which a window is cut over the fracture site.[1]

There are other therapeutic measures applied by hypodermic injection at the fracture site. Tincture of iodine, adrenaline chloride solution, 1 to 1000, blood serum or the patient's whole blood,[2] and various emulsions of bone-marrow or phosphates have been advocated. Osmic acid has been used.[3] Marcozzi[4] proposes a filling for bone cavities something like the Mosetig-Moorhoff bone plug. He leaves out iodoform and mixes equal parts of calcium carbonate and phosphate sterilized by heat. These are shoveled into the cleansed bone cavity. An emulsion of these salts in sterile liquid vaseline has been used in non-union. Bone filings have been advocated by Farr.[5] and Kauffler.[6] Bone obtained from the morgue is dried, ground to a powder, mixed with petrolatum, and sterilized by being boiled in a flask for two hours. A small syringe with a long needle is used to inject the emulsion around the fracture site of fresh or ununited cases. As the bone cells in the emulsion are dead, they do not act as a centre of osteogenesis, but the whole may act as a medium of transmission for the outgrowing capillaries.

[1] Sprengel, Arch. f. klin. Chir., Bd. cv, Heft III, 599.
[2] Lyle, Ann. Surg., 1913, p. 284; Bier., Med. Klin., 1905.
[3] Onorato, Gaz. Med. Lombarda, 1913, p. 9.
[4] Riforma med., Naples, xxx.
[5] Journal-Lancet, xxxiii, 432.
[6] New York Med. Jour., November 21, 1914, p. 1013.

Operative Treatment.—The simplest measure is drilling. Through small skin openings drill holes, running diagonally into the shaft, are made at the fracture site in both fragments. This opens several fresh areas of bone surface and theoretically stimulates bone regeneration. The limb is immobilized, and a satisfactory result often follows in instances of fibrous union. It is hardly possible to eradicate in this way a pseudarthrosis. Complete open operation to expose the fragment ends is a more radical step. All fibrous tissue is removed by sharp dissection, the ends are freshened by a saw or chisel, and they are brought into approximation by reposition or the use of internal splints. Wires, kangaroo tendon, or catgut are used to fasten the fragments together, but they are not very efficient in the larger bones. More reliance should be placed in a carefully applied plaster encasement, put on while the bones are in contact aided by pressure in the longitudinal axis. The bone ends may be cut to interlock, and fixation can be aided by nails or ivory pegs. If one bone, the tibia for example, is shortened by the end trimming, the fibula must be exposed and shortened a similar amount to allow approximation, if this type of repair is adopted. Foreign material is inadvisable in these cases. A Lane plate, however, applied after exact approximation of the freshened surfaces, will often promote union, if the subsequent immobilization is adequate. On the other hand, some cases fail in spite of compliance with every rule for the application of the internal splint.

The very best treatment is the inlay or medullary graft of autogenous bone. (See chapter on Treatment.) Several hundred of these cases are now on record in the literature, and, if infection is not present and radical freshening of fragments is performed, success can be looked for in a large percentage of operations. Non-union with pseudarthrosis is the most difficult of all types to cure. The entire mass of the false joint must be dissected away. It frequently is attached to nerves and bloodvessels, and the process of removal is very tedious. For this type I always employ an intramedullary graft. In a limb with two bones, one of which is shortened by the freshening process, the inlay or medullary graft can be employed with the avoidance of shortening the second bone, full length of the part being thus retained.

On the whole, conservative methods should be used for failure of union unless there is obvious reason for radical operation. Loss of function and time, necessity for freedom from treatment for economic reasons, and the physical and psychological effects of confinement, indicate operation. This operation should be undertaken only by surgeons of experience in the line of work. Hawley's 53 cases afford a means of estimating the value of conservative treatment. Two cases resulted in complete failure, 3 were still under treatment at the time of the report, and 6 were fractures of the neck of the femur in which the function was fair without corrective treatment. 42 cases remained, 31, or 74 per cent., were cured by non-operative means, 11 were operated on only after conservative treatment had failed.

In the upper extremity reimmobilization after correction can be

practised, but weight-bearing cannot be used. Consequently the ununited fractures of the upper extremity will more often demand operation. Hawley had only 4 successful cases out of 10 treated by conservative means, whereas in the lower limb reimmobilization plus weight-bearing gave 28 cures out of 34 cases.

Vicious Union and Deformity.—Vicious union, malunion, and deformity under ordinary circumstances, are a reproach to surgery. They can nearly always be avoided by careful watching in the course of bone healing, if there has been efficient reduction. In some fractures ultimate deformity must be expected. In Colles's fracture, except in adolescents, there is always some degree of permanent deformity on account of the crushing shortening of the bone. Fractures of the neck of the femur and a certain small amount of overriding in torsion fractures of the leg and thigh are to be expected unless an anatomical reposition is effected by operative means. Malunion is caused by incomplete reduction, especially by the attendant's failure to use and maintain powerful traction in order to bring the fragment in apposition. The surgeon must have a well-grounded knowledge of the mechanical effect he wishes to obtain. In the leg he must allow for the normal slight bowing, if both bones are fractured, and not put the leg *perfectly* straight. If the reduction is not in order of the physiological alignment of the limb, no splint or external application or massage will produce a happy result. Alignment in the limb is extremely important so far as final function is concerned. Near joints special problems arise in fractures, and esthetic appearance must be sacrificed to functional result when the methods to obtain the two conflict. Callus and fragments must not interfere with the joint motion, and at the same time the alignment of bones must restore the limb axis, so that the lines of weight-bearing stress will pass normally across the joint and the articular surface will functionate without trouble.

Other causes for malunion are inefficient splinting, too early weight-bearing, and lack of coöperation between patient and surgeon. The splint or dressing must hold the alignment of reduction and in oblique or torsion fractures must also provide for maintaining traction. If the patient will not coöperate with the surgeon, if he puts aside his splint too soon, or does not lie quietly under the restraint of extension apparatus, deformities are to be expected. Too early weight-bearing is also of importance. The callus may not be solidified, and as it gives under body weight deflections in the supporting line follow. About joints, especially after malleolar fracture at the ankle, condylar fractures of the femur and humerus and fractures of the shaft of the femur, secondary changes of angulation and shortening occur, if too early passive motion or weight-bearing is allowed. The joint fractures on which weight is borne too soon become painful, there is alteration in the bone structure to accommodate the new lines of muscular stress and weight-bearing, and buttressing changes result much like those found in hypertrophic osteo-arthritis. Fracture through the

shaft of long bones may have angular deformity even with an end-to-end apposition. This deformity produces shortening and changes in the weight-bearing lines which increase the cross strain at the fracture site and affect the action of the neighboring joints above and below.

Treatment of vicious union depends on the amount of deformity and the age and location of the fracture. If the fracture is recent and the callus is soft, manipulation with traction may straighten the limb into correct alignment. When joint fractures are concerned, an effort should be made to correct the deformity and to place the limb in a position of rest until solid union has followed. Should a fragment or excess callus interfere with functional movement, open operation for removal or for replacement should be undertaken.

Fracture viciously healed with a solid callus and no overriding and shortening can be refractured by an osteoclast or a chisel by an open operation through a small incision, after which the limb is straightened and reimmobilized. If the deformity has been of long standing, the muscle and fascial contractions on the concave side of the limb may interfere seriously with correction. In such a case they can be partly divided subcutaneously before final correction is forced, so that the fragment ends are not carried past each other for overriding.

Open operation is used for osteotomy followed by simple reposition or the use of internal bone splints. Complete exposure of the mal-union permits an exact knowledge of the fracture. Excess callus can be removed, and the bone is chiseled or sawed through and the limb brought into line. In some instances a V-shaped fragment is cut out as aid in straightening. This is necessary in long-standing cases with muscle contraction. Lane plates, nails, or screws are used to hold fragments together if they tend to slip about. The best repair does not involve the use of an internal splint. Simple reposition leads to union in a normal length of time. In the making of a straightening, the periosteum is seldom completely cut through. If it is widely reflected from the ends of the fragments, it must be carefully folded or sutured over before the wound is closed. If a plate is applied, it should be put on outside of the periosteum.

Fractures near or into joints are to be judged each on its own findings. Pott's fractures with wide dislocation laterally of the talus are amenable to operation. The treatment is described in the chapter dealing with the bones of the leg. Other joint fractures with restricted motion are more safely treated by excision of small fragments than by attempts at replacement. A wide range of joint motion must be secured and the limb left in fixation until bone regeneration has quieted down.

(*f*) *Nerve Injury and Inclusions*.—Nerve injury caused by the trauma of fracture is one of the early local complications. The late complication is a callus affair. Nerve pressure which causes pain or paresis may start in the third to the fifth week. It is caused by the callus. The callus may grow around and bury a nerve completely.

As shrinkage and ossification ensue, the pressure gradually strangles the nerve fibers until function is suspended. The radial nerve (musculospiral) as it passes around the humerus and the ulnar nerve at the elbow-joint, are the ones most frequently involved. They should be radically freed from the callus, and transplanted some distance away, well wrapped in a sheet of fat. If the operation is aseptic, one need have no fear of recurrence. In the last year I have operated on six cases of this character. In one the radial nerve had been out of function so long that I feared the axones were destroyed at the site of pinching. The nerve was severed, therefore, and the compressed portion was excised completely, an end-to-end anastomosis of the cut portions being possible without a plastic. Fine linen sutures through the sheath drew the cut surfaces together. After ten months there was a functional return which promised to become nearly perfect.

Cotton[1] has recently called attention to a separate class of nerve lesions limited largely to the ulnar at the elbow. There is pain radiating down from the elbow to the last two fingers, some skin numbness in this region, and a partial paresis of the intrinsic muscles of the hand, shown by weakness and clumsiness in execution of the finer finger movements. Many of the patients with these complaints have not had a fracture at the elbow, but there has been some trauma there, and scar tissue has formed which gradually contracted and fixed the nerve where it lies in the epitrochlear groove. Movements of the elbow, especially flexions, fall on the nerve and cause the symptoms. The cure is complete removal of the nerve from the bone bed and its transplantation in a site anterior, wrapped in a mass of fat taken from the thigh or abdomen. I have so transplanted in three instances; in one the nerve sheath was red and hemorrhagic in appearance. The results are satisfactory.

Snapping callus, "Cal à ressort," is a callus complication which occurs in the radius and fibula. Toussaint[2] describes it as an objective or subjective click at the callus level, caused by supination of the wrist or abduction of the foot. It is caused by friction of an angular bone prominence which may be soft or thoroughly calcified callus, upon the interosseous membrane. It causes some decrease in function of the limb. The roentgenogram will not show it unless it is thoroughly calcified. No open operation is needed for its removal, as immobilization leads to its absorption.

(*g*) *Development of Tumors.*—Causative relation between trauma and sarcoma of bone is well established. There is a question, however, whether sarcoma follows a fracture. Considering the number of fractured bones, osseous sarcomata would be common if fracture were the cause. Murphy[3] states that he does not believe sarcoma follows fracture, but that it follows trauma, which causes pain and contuses a bone without breaking it. Most cases which have been

[1] Boston, Med. and Surg. Jour., clxxii, No. 13.
[2] Rev. d'orthop., March, 1913.
[3] Clinics, i, 780.

reported in connection with fracture are really pathological fracture; that is, the sarcoma was primary and the cause of weakening the bone. (See chapter on Etiology.) Coley has reported a case of bone sarcoma which seemed to follow fracture. Griffin[1] reported a case of sarcoma of the femur, which followed an operation for plating a fracture. I have had one case in the jaw. The fracture occurred eighteen months previous to the patient's seeking treatment for a tumor of the mandible at the same site. The jaw was removed and the sarcoma verified. The fracture was healed and the tumor mass spread from that area. New growths do rarely appear at fracture sites, from a few weeks to many years after the injury. If they are benign in character, they are removed for cosmetic purposes or on account of pressure symptoms. Every tumor mass after fracture should be closely inspected and studied by roentgenogram and the microscope. Theoretically sarcoma may result from irritation or from an atypical overgrowth of the embryonal cells which form callus. Radical removal of the affected part of the bone with transplantation of autogenous bone to fill the defect is the treatment when metastases and extensive local spreading are not evident.

2. Arrest and Exaggeration of Growth are not Common Occurrences.—Arrest follows, for the most part, epiphyseal injuries, and the subject is discussed under Fractures of the Wrist, where the condition is most often found. When a growing epiphysis is injured and premature calcification follows, the growing function is lost. The bone involved ceases to grow in a corresponding ratio to a companion bone in the same limb or the corresponding bone of the other limb. The result is a curvature and functional loss. Another epiphysis in the injured bone may take on enough exaggerated growth to make up the deficiency, so that ultimately there is no shortening. I have had no cases of cessation of growth after fracture of the epiphysis of a long bone.

Exaggeration of growth is seen in the patella. After fracture, or even after trauma, which does not produce fracture, this sesamoid enlarges. The new growth is caused by proliferation beneath the periosteum, and in some cases the process of ossification extends into the patellar and quadriceps extensor tendons. This is comparable to parosteal bone growth, ossifying myositis, etc. Large bony growths from callus are really excess callus formation. When the whole shaft of a long bone thickens and presents an appearance of exaggerated growth, the first thought must be of an *osteomyelitic* or a syphilitic process. A roentgenogram will aid in establishing diagnosis. True giant growth may be localized in one limb and may not be noticed until after a trauma. I have seen one case of localized giant growth affecting the leg of a boy about eight years old. Both bones are affected, and the soft parts are also. There is no edema or changed appearance, other than the increased size, and function is normal.

[1] Med. Record, 1913, p. 650.

3. Neighboring Joint Complications.—Neighboring joint complications are manifested by stiffness and restricted motion. These complications *do not include the results of articular fractures,* but are caused by local conditions in the limb extending from the fracture site or by treatment.

If the fracture is near a joint, unrecognized fissures may extend to the joint. Hemarthroses, distention of the joint, or even suppuration may result. Chaput[1] suggests that there are many unsuspected instances of suppurative arthritis after fractures, and advises the injection of a solution of methylene blue by joint puncture to distend the synovial membrane slightly. Coloration of the pus at the fracture site proves the existence of a connection.

Stiffness and restriction of motion in other than joint fractures may be caused by conditions arising within the joint, about the joint, or in the limb as a whole. The conditions arising within the joint are:

(*a*) Hemarthrosis, which causes a distention of the joint capsule and leads to subsequent weakness or the formation of adhesions within the joint. This capsular weakness is counteracted by contraction of periarticular structures which ultimately causes restriction of motion.

(*b*) Suppurative arthritis of hematogenous origin rather than of extension through fissures mentioned in the preceding paragraph.

(*c*) Traumatic arthritis with or without effusion characterized by pain and much loss of function and followed by great restriction of motion. The pathological result includes intra- and periarticular adhesions and contraction of the capsular structures.

(*d*) Remote changes within the joint induced by positions of malalignment of a limb. In the leg these often lead to the buttressing, bony changes described previously, which are much like osteo-arthritis. These are particularly prone to appear in elderly people, so that the relative effects are greater in the old than in the young.

The conditions about the joint which cause stiffness are: (*a*) Contraction of the capsular ligament following stretching from prolonged extension as a Bucks, or the contraction and atrophy subsequent to non-use and long immobilization. The tissues may be shortened by permanent cicatricial change from infection of open fracture, or by aseptic inflammation.

(*e*) Contraction and fixation or stiffness in the pericapsular tissues such as muscles and tendons which become adherent or atrophied.

Conditions arising in the limb as a whole are edema and circulatory interference from any cause such as a large callus, tight splints, or vessel injury, shortening of muscles and tendons from disuse, atrophy, or adherence to callus or nutritional disturbance, such as in Volkmann's contracture.

The treatment of neighboring joint complications is largely that of prophylaxis. Early steps must be taken to diminish swelling and edema of a limb. Hot and cold applications, aspiration of joint

[1] Presse Médicale, Paris, xxiii, No. 16.

effusions and hemorrhages, and incisions through the fascia may be used. The parts not immediately involved or whose immobilization is not essential to proper treatment of the fracture must be left free. This is essential in the hand. The fingers must be free whenever possible and their use and motion encouraged from the first. Active and passive motions of joints must be used when no pain or reaction is caused, not before. Undue stretching of the joint capsule or prolonged immobilization in a fully extended position of the joint must be avoided. Time, massage, passive and persistent active motions and use will cure most cases of joint complication.

4. Muscle and Soft Part Changes.—Muscle and soft part changes have been partly mentioned in preceding sections. The skin and subcutaneous fat may show atrophy. The skin seems thinned and anemic, or in some cases shiny and red or cyanotic. The muscles are distinctly atrophied if a long immobilization has existed. The muscles lose elasticity and bulk, and they may be fixed to callus, torn fascial planes, or periosteum. When a permanent dressing is removed and the patient starts to use the limb or to expose it to normal surroundings, there follows swelling of a few days' duration. Use and massage overcome this. Young persons overcome the atrophy, which is nearly always one of disuse and rarely dependent on nerve changes. In elderly persons massage and electricity often fail to make complete restoration.

5. Bloodvessel Complications.—Bloodvessel complications are nearly always early. Late changes may be found in veins when the patient begins use of a limb. Callus or malposition may cause circulatory interference and passive congestion with enlarged veins. Late thrombosis and embolism are rare, but there are cases recorded in the literature. Embolism of the pulmonary artery is the one most feared. I have seen one case in the third week after fracture of the femur. Small emboli, often septic, have been found in the lungs or pleura before thrombosis in the leg was suspected. Le Conte's investigations of fat embolism seem to disprove the danger of pneumonia from this source. The hypostatic congestion is probably the most important factor.

Late gangrene may follow injury of the arteries which results in thrombosis or in circulatory disturbance in persons with sclerotic vessels. Age has much influence in the bloodvessel complications. Traumatic aneurism is rare, but occurs in the popliteal after fracture of the femur. It may be late in appearing when the fracture is unreduced and the vessel is stretched over the lower fragment.

CHAPTER IV.

SYMPTOMS, SIGNS, AND DIAGNOSIS OF FRACTURE.

SYMPTOMS AND SIGNS OF FRACTURE.

When we speak of symptoms of fracture we mean something subjective, lying wholly within the patient's consciousness. By signs we mean something objective rather than subjective. Signs, however, often overlap into symptoms. Pain may be simulated so that the surgeon cannot rely on the evidence furnished by it, but the trained examiner in doubtful cases depends less on the patient's complaint of pain and more on the elicitation of signs of suffering on reiterated pressure or jarring of the suspected part when the patient's attention is distracted. Crepitus also may be subjective; that is, it may be felt by the patient and not by the surgeon. Symptoms and signs may be enumerated as:

1. Pain.
2. Loss of Function.
3. Deformity.
4. False Mobility.
5. Crepitus.

1. **Pain.**—Pain is the most important finding in fracture. It is constant except in some instances of pathological fracture or in conditions in which normal enervation is lessened. When the patient keeps the affected part quiet after injury, the amount of pain varies with the amount of injury and local reaction. Fracture caused by direct violence with bruising and laceration of the soft parts, with swelling and hemorrhage, would be expected to cause much spontaneous pain. Incomplete fracture and fracture from indirect violence will probably have less spontaneous pain at first. All unrecognized fractures cause pain, if use of the part is persisted in. Pain symptom is usually elicited on active and passive motions of the bone. If a long bone of a limb is broken, it becomes painful when active contractions are made of the muscles attached to it, either in functional use or in resistance against movements which are applied as tests. Efforts to extend the forearm held by the surgeon cause pain in the ulna when it is fractured, and the broken radius is painful when flexion efforts are restricted. Twisting or rotary movements applied gently to the arm or leg elicit pain at the fracture site. The jarring of a bone by slight knocks in its longitudinal axis or in the transverse axis by a percussing finger tapping along its continuity causes pain. Near joints, pencil or digital pressure applied over the bone will discover in obscure fracture a recurring point of pain. The pain of the bone lesion, which can be differentiated

from the painful injury of the soft parts, is persistent and lasts for ten to fourteen days. Its prominent characteristic is that it recurs in the same place. Some fractures give no other symptom than pain. A crack across the radius at the wrist, or a green-stick fracture of the clavicle, or a crack in the fibula just above the ankle, all fail to give deformity, crepitus or false motion, but do give this recurring pain. This finding is consequently the most valuable and the easiest obtainable in fracture. The roentgenogram is the only sure evidence that is comparable to it, and then a poor exposure will fail to reveal a fracture which can be diagnosed by pain symptoms.

2. **Loss of Function.**—Loss of function is variable, depending on the extent of the fracture and complicating effects of the trauma. The functional disturbance may arise from two sources: from the lack of support of the part caused by loss of continuity of the bony skeleton, or from actual pain or fear of pain. Bruises and contusions involving muscles, tendons, periosteum, and joint surfaces often cause temporary loss of function in a limb. This temporary disability ceases under simple therapeutic measures. The functional disturbance of fracture is prolonged. Possibly it should be called a disturbance rather than a loss of function, particularly as applied to incomplete and obscure fractures. Complete fracture of the bones of a limb leads to unmistakable loss of function.

Cases of fracture which have not been diagnosed often show a functional disturbance of greater importance than the type of fracture warrants. This finding outlasts pain.

3. **Deformity.**—This sign concerns gross deformities apparent to inspection of the part and the various displacement of fragments described in the chapter on Pathology. Shortening, angular deformity, or overriding may be apparent on inspection of a part. No observation of deformity is of value as a symptom or in diagnosis unless previous injuries are considered and the part is compared carefully with the corresponding uninjured portion of the body, if there is one. Mensuration in both longitudinal and transverse axes and circumference betrays the existence of deformity. Length is determined by measurement from fixed bony points on the skeleton which are palpable or subcutaneous. Where there is much subcutaneous fat these points are difficult to locate exactly, and there must be allowance for error on the surgeon's part and for variation in the length of limbs. (See Fractures of the Femur.) Two limbs subjected to measurement for comparison must be in the same relative position toward the trunk, making an identical angle with the long axis of the body. If one is distended with effusion or inflammatory exudate, these conditions will influence measurements.

These same swellings also cause modification of the external appearance of a limb and produce deformity themselves, or enhance the deformity of fracture. Subfascial hemorrhage and extravasation increase the transverse diameter of a limb and shorten its length if the bone continuity is lost.

Ecchymosis from fracture is also a valuable sign, particularly in the obscure fractures about joints or deep structures, like the small bones of the wrist and ankle. The discoloration does not appear at once unless the superficial soft parts have been damaged; it shows in the course of a few days and may last for three or four weeks. There is

FIG. 22.—Bleb formation after ankle fracture. Practically no deformity present.

tendency for the blood to burrow in the direction of the fascial and muscle planes and appear at great distance from the fracture area. Bleb formation is present in many cases (see Figs. 22 and 23).

4. **False Mobility.**—False mobility or a false point of motion is pathognomonic of fracture when it is found existing in any part of a

FIG. 23.—Bleb appearing on fourth day after ankle fracture.

bone when motion does not exist normally. This sign is not demonstrable in all fractures. In impactions, as depressions of the skull vault, in fractures of the smaller bones of the body, as in the wrist and ankle, or in fractures near joints where one fragment is small and is held in place by untorn ligaments, one would not be able to find a

false point of motion. Some bones are slightly elastic and give an impression of slight mobility which may be misleading. The ribs and the sternum, particularly the ensiform process, are examples.

A false point of motion is demonstrated in complete fracture of a limb by simple raising of the part gently by a hand placed under the site of fracture. Angular deformity, pain, and sometimes crepitus are at once produced. The fractured bone may be grasped between the fingers of both hands, one above and one below the break, and the fragments are moved in opposite directions to establish looseness. The distal end of a long bone may be grasped and the limb rotated, the fingers of the other hand resting on the proximal fragment feeling to determine the false point of motion. The fragments may require rocking with considerable force, or small fragments near joints can be grasped between the thumb and index finger and moved in the direction of the plane of fracture. Under some circumtances repeated attempts are necessary to assure the surgeon that he is dealing with false motion. Abnormal motion in fracture just below the head of the humerus, radius, and femur is searched for by the attendant rotating the shaft of the bone and endeavoring to feel the head to ascertain whether it takes up the shaft motion or fails because of lack of continuity. Wide rotatary movements are not needed and lead to confusion, because the head may be moved by the attachment of untorn ligaments. Infractions also cause the head to move with the shaft and lead to error. Movements of skin and soft parts over the bone must not be confused with mobility of the osseous structure itself.

5. **Crepitus.**—Crepitus is defined as a grating sound or a similar tactual sensation perceived by the patient or the surgeon as he manipulates the bone. It is caused by the broken ends being rubbed together and depends on the previous sign of mobility of the fragments. The eliciting of even the slightest click of unmistakable crepitus is positive evidence of fracture. Experience leads to quick recognition of this valuable sign, and it can often be felt by gentle and nearly painless manipulation, which should not be repeated if positive results are obtained. When gentle motions fail, forcible exertion is not indicated, especially if pain is induced. Muscle spasm from pain may hold fragments immovable, and diagnosis of fracture can be made on other findings, or an anesthetic can be given to permit full examination. A condition of normal joint crepitus which is present in many persons may confuse the examiner. The joint crepitation is transmitted along the bones which enter into the articular formation, so that motion will give a false feeling of crepitus. This feeling is generally softer and smoother than the sharp click or grating of fractured osseous surfaces and can be eliminated by experience and by testing a corresponding uninjured part of the body.

Other means of obtaining crepitus are the use of the flat surface of the palm over the chest when fractured ribs or scapulæ are concerned and direct auscultation with the stethoscope. Deep inspiration or pressure movement of the ribs and scapula may reveal a crepitus not

found in other ways. Certain types of fracture are not likely to give crepitus for obvious reasons. They are:

1. Marked overlapping.
2. Separation of fragments, as in the patella and olecranon.
3. Impactions and locked denticulate fragments found in Colles's fracture and in the femoral and humeral neck.
4. Incomplete fracture, as sprain and green stick.
5. Buckling fractures.

DIAGNOSIS OF FRACTURE.

Diagnosis is made on a combination of the above symptoms and signs. All may be present in a fracture; only one, pain, may be present in others. No diagnosis should be made by rule. The examiner must use every means at his disposal to verify or disprove fracture. Many instances of broken bones are not diagnosed and are consequently improperly treated, because all the signs are not found. This is particularly so in regard to crepitus, which should be relegated to its place of relative importance, namely, the last. Grave errors in diagnosis and risks of liability are run by insistence upon this sign as essential to clinical diagnosis of fracture. The greatest reliance can be placed in pain, in recurring soreness and tenderness at one point on repeated examinations. If there is no other plausible reason with a history of trauma, diagnosis of fracture is quite safe. Rarely other conditions may be mistaken. As I write this I have in mind a case admitted to my service in the Cook County Hospital. He is a young lad who has injured his left hip in a fall. No satisfactory physical examination could be performed by the doctors admitting him to the hospital, as he would writhe about with pain if attempt was made to examine the right hip. The thigh is held in flexion and some inward rotation. There is evidently slight active use of the leg, and a diagnosis of fracture dislocation was put on the admission card. A short observation aided by a roentgenogram was sufficient to prove that the condition was an acute infectious epiphysitis of the upper end of the right femur.

Examination of the patient must be thorough. History of any previous accidents and of the exact nature of the present trouble must be obtained. Evidence of contusion, soiled clothing, abrasions, or old injuries must be searched for, and the patient's statement must be weighed in the light of their evidence. The clothing of the injured and corresponding part should be removed for complete examination and comparison. One of the most helpful points of evidence in complete fracture is the inability to retain a reduction which may be easily made. This differentiates from dislocation. Multiple fracture is frequently overlooked. All manipulations must be gentle and must be undertaken after securing the patient's confidence. Roughness leads to increased pain and local reaction about the fracture site. Muscular contraction and spasm, increased displacement, the separation of an impacted or dentate fragment when that might not be wished

for, result and may cause embolism, nerve injury, or bloodvessel damage with gangrene. When satisfactory examination cannot be made otherwise, an anesthetic may be given, but reduction and treatment must be prepared for at the same time to avoid repetition of the anesthetic. Rough manipulations must be avoided.

Reference is made constantly in this text to the value and use of the Roentgen rays, and the illustrations used for graphic description of the various fractures are tracings of roentgenograms. It must be said, however, that too much reliance should not be placed on the roentgenogram, nor should it be allowed as legal evidence in fracture cases. Too many factors enter into its make-up. Time and angle of exposure, the skill of the individual making the picture, and the experience of the one interpreting the picture allow a great divergence of opinion. Knowledge obtained from the plates should be applied by clinical examination before full diagnosis is made. Complete knowledge of the extent and planes of fracture cannot be obtained from one plate. As prescribed in ankle fractures, a roentgenogram in two planes should always be made, if any plates are possible, and no definite knowledge of impaction at the hip or complete displacements at other sites should be asserted without stereoscopic views. The one interpreting the plate should have a wide knowledge and experience in bone pathology, coupled with an anatomical knowledge of growth of bone and epiphyses and their appearance in roentgenogram. Routine use of the Roentgen rays preliminary to the treatment of *all* fractures is impossible and not essential. Palpable deformities can be reduced early with much relief to the patient without a wait of hours or days for a picture. A plate made after reduction, when the patient is in condition to be transported to the room for exposure, or can walk to a laboratory, is very helpful if the reduction is not complete. Most dislocations are reduced when first seen by the surgeon, and roentgenograms of them later are for the purpose of confirming the reduction and of checking upon some of the small fractures that accompany them. Obscure injuries and dislocations, suspected or known fractures of the pelvic, skull, wrist and ankle bones and about joints like the hip and shoulder, are wisely subjected to Roentgen examination if it is convenient.

A roentgenogram taken to show end-results or late in the course of a fracture has no value except in those cases of failure of union to determine the amount of callus or to help decide on operation for malunion. The ultimate test of the fracture result is functional and not anatomical. Anatomical reposition seldom occurs except in open operation, and not always then. If the patient secures a functional result without gross deformity, no Roentgen examination is necessary, and slight displacements which are present in a large majority of cases might be misinterpreted by unskilled observers and lead to trouble. These displacements become effaced in the course of time when functional use readjusts the bone structure in accordance with Wolff's law.

CHAPTER V.

TREATMENT OF FRACTURES.

In many divisions of medical science we have devoted ourselves to the refinements of laboratory diagnosis, to brilliant surgical exposures of lesions or to an equally masterly repair of them. Fracture treatment has suffered from lack of this attention. If one studies Hamilton's *Fractures and Dislocations*, it seems almost impossible to believe that the older masters of that type of surgery were able to know as much of the refined detail of fractures as they did without the help of the Roentgen rays. A large majority of newly graduated medical students today have a wonderful and thorough knowledge of intricate pathological processes and laboratory tests, but many of them are very deficient in knowledge of practical fracture treatment. The roentgenogram, asepsis, and operative treatment have deprived the profession of many members who without these aids would have become expert diagnosticians of unopened traumatic bone lesions. It might also be said that treatment has been neglected until Lane and others have forced a desire for better results on the profession and the public. There is now a reversion to former keenness of diagnosis. Open operation and better knowledge of immediate pathology have really sharpened the practices of non-operative care, and good can be traced from the many unfortunate operated cases of the past few years. The subject of neglect of fractures, the necessity for attention to them and for training of men in that field has been discussed in most of the influential medical societies of the world and caused a tremendous outpour of literature in the last ten years.

Treatment may be divided into:

Immediate treatment; reduction, the factors obstructing and favoring it, and means of obtaining it; traction, fixation and different types of splints used to maintain it; massage and accessory treatment. Methods which involve a cutting operation, and the arguments for and against such procedure, are contained, as much as they can be separated, in the chapter on Operative Treatment.

IMMEDIATE TREATMENT.

It is artificial to speak of first aid, or immediate treatment and permanent treatment because the two merge, and in any treatment of the fracture itself in the beginning, the surgeon should bear in mind the indications for permanent cure and restoration of function. Every case must be judged separately and certain factors must be weighed

in non-operative as well as in operative treatment. The surgeon must consider: (1) what is the best treatment for the fracture before him from the standpoint of the patient. The patient's age and physical condition, his environment and the exact position of the fracture itself must be weighed; (2) what method of treatment will cause the least distress and pain for the patient after its application; (3) what method will give shortest disability and the best function; (4) what are the surgeon's own limitations in regard to ability in diagnosis and treatment; (5) what are the medicolegal aspects of the case.

As regards the patient, his age and physical condition are important factors. The aged and those with weakened cardiac action or organic diseases cannot be subjected to recumbent rest in bed for fear of pulmonary and other complications. The bones under certain conditions of age and disease do not regenerate quickly, nor can weakened patients withstand the weight and confinement of massive splints and dressings. Light splints made of moulded plaster, aluminum, wire and leather may be indicated. Nervous patients will not endure splint confinement nor long periods of extension. Complications of other injuries and shock of accident must be kept in mind, and no treatment or manipulation which will cause more pain or induce "noci association," as described by Crile, should be attempted. Any illnesses or dyscrasias should be inquired into. Consequently the first step is a most painstaking general examination or survey of the patient. This examination should be gentle, the symptoms of fracture should be solicited without disturbance, and although treatment from the very start must look toward restoration to normal, it is better to postpone thorough diagnostic examination of the site of fracture until one is ready to proceed with reduction and fixation, or until the other factors have been weighed. Rough manipulation causes pain and reflex muscle spasms which defeat attempts to obtain diagnostic information and interfere with reduction. When the patient is at a distance from the surgeon, in a farm house, or so located that observation of progress of the condition cannot be safely carried out, the type of treatment must be of such character that it will be safe under the existing circumstances. When possible, hospitalization of fracture cases should be insisted upon until recourse to roentgenogram is obtained and the subsidence of acute conditions permits safe dressings out of the surgeon's immediate reach.

The earlier the patient is seen after accident, before swelling and pain with muscle spasm have developed, the easier it is to make quick examination and an accurate diagnosis. The exact type of fracture should be determined from the history and the examination. Local complications must not be overlooked. Small lacerations of the skin or fascia may not seem to penetrate to the bone, but they very frequently do by indirect routes and should be viewed with suspicion. Major fractures are better diagnosed and treated under anesthesia. If this is desired and transportation to another place or hospital is

necessary, the immediate dressing should be one which fixes the limb in the position of displacement and holds it firmly. Even this treatment must not be applied until the surgeon is assured that the fragment ends will not injure important nerves and bloodvessels.

Some cases which come under the classification of "operative reduction" will need exclusion from the line of simple treatment at once. Many of these, however, are not subjected to immediate operation, and a dressing is applied for protection and security against pain, or extensions of different kinds are used to preserve muscle length and to avoid spasm.

Reduction.—If reduction can be made, the immediate treatment is pursued in direct line of a permanent one; that is, the splint or fixation is used which will cause the least distress to the patient in its application and which will give the quickest and best end-results. No one splint should be used for certain types of fracture unless that splint is *open to modification to suit the individual case*. The splint should aim toward permanent correction in accordance with the previous statements; it should afford protection from outside jars and exposure; it should rest the part, and it should lessen the pain and the danger of complications.

The surgeon should know his own limitations in a diagnostic and therapeutic way, that he may not be led into errors of ignorance which will cause unhappy results to the patient and himself.

The medicolegal aspect must also receive attention. This involves relations between the surgeon and patient, between the surgeon and employers' liability laws and insurance, State accident insurance, and various fraternal organizations and corporations. The relation most important to the surgeon is his own liability to the patient to exercise a reasonable degree of skill. A large percentage of personal damage suits against medical men arise from fracture cases. I have been asked questions on the status of first aid and found an interesting concrete example in the Queries and Minor Notes column of the *Journal of the American Medical Association*.[1] The questioner wished to know if "first aid" in fractures had been defined in his own State (South Dakota) or Illinois, because it concerned the matter of a fee for a roentgenogram and reduction of a specific case. The insurance company concerned was not willing to pay for these things as "first aid." The *Journal* defined first aid as the temporary measures carried out in emergencies by anyone, layman or physician, preliminary to the institution of a definite line of treatment by the physician in charge of the case. They believed that "first aid" ceased and definite treatment began when the patient had arrived at his home or a hospital and had been turned over either to his own physician or to the hospital surgeon, or wished to continue the services of the physician first called. In large cities where many persons who suffer accident are transported to hospitals at once there is no "first aid" at all, unless

[1] August 29, 1914, lxiii, No. 9.

Gerster's turnbuckle (see Operative Treatment) etc., are not needed when one has mechanical extension.

Fig. 24.—Table ready to receive a patient, foot brackets attached and in position.

The portable apparatus of Ridlon answers nearly all purposes for forcible mechanical leg extension. I use it in operating on cases at a distance. Through use of t sufficient force can be exerted to pull out a strong thigh or leg until the desired length is obtained. It

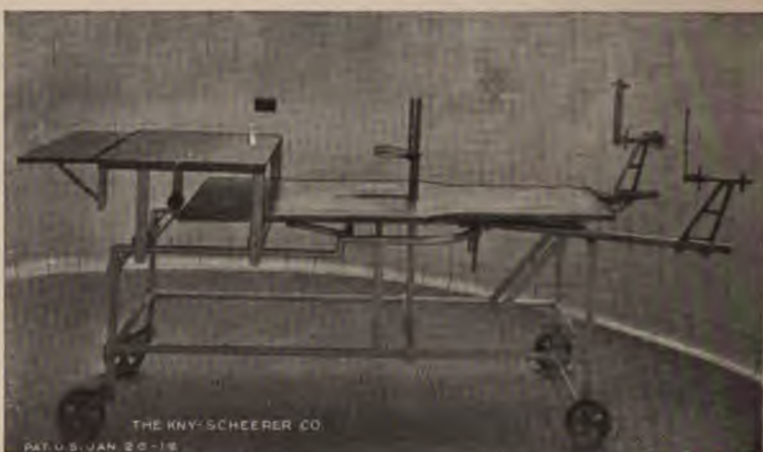

Fig. 25.—The foot portion of the table is dropped so that the operator can apply leg or body encasement easily while traction is maintained.

needs two tables set close together and an assistant to hold the extended leg and tighten the traction. This holding is tiresome, expecially when body casts are applied.

Reductions are early or late; there is much to be said in favor of early reduction, because in recent injuries the muscles offer less resistance and the effusion of blood and lymph has not yet distended muscles, fascial boundaries, and skin to cause shortening and deformity of the limb. Consequently in accordance with the previous statements there should be no delay in reduction.

There are certain factors which cause difficulty in reduction. These are:

1. Extreme displacement of fragments which are pulled on by muscles or forced far out of position by the trauma.
2. Interposition of muscles, fascia, or small bone fragments between the fractured parts.
3. Long spiral fractures with overriding of fragments, comminution, impaction, and mashing destruction of cancellous bone.
4. Other mechanical hindrances as muscle spasm and primary effusion beneath a heavy fascial envelope.
5. Beginning callus or secondary infiltration of the parts at the site of fracture.
6. Other injuries which are more important in a general way. Local injury of bloodvessels and nerves, or the formation of blebs, may make impossible the application of traction necessary for reduction or of apparatus to hold it.

Factors which favor reduction are:

1. Simple type of fracture with little displacement.
2. Little swelling and local reaction.
3. Early efforts, before muscular contraction and swelling interfere.
4. Anesthesia, local or general.

Not all fractures result in displacement and consequently not all need reduction. Those not needing reduction are usually linear fractures through the large bones. The skull, the ilium, or the scapula also furnish examples. Other bones, like the ribs, or one of two bones in the forearm and leg, may be broken and held in place by the uninjured companion bone. If we include the possibility of operative aid, practically no fracture displacement is irreducible. Some may better remain unreduced where there are obstacles in the way. Displaced fractures of the pelvis which will not yield to manipulative efforts are of this type. Impacted fractures of the femoral neck in some elderly people are considered irreducible from choice, and others with impaction and little displacement are often not disturbed for fear of increasing the deformity.

Fractures about and into joints are a law unto themselves. Most of these are to be placed in the operative class, because their reduction is often dependent on the integrity of the ligaments, and these may be torn or injured so that they are not available for reductive traction. They should be given very early reductive treatment, which if not shown satisfactory in the roentgenogram must be supplemented by operation. If reduction cannot be anatomically perfect, it must be that which will fix the joint in position to render the greatest use.

A very slight deformity in a joint fracture may result in disproportionate disability. This is because a change or tilt in a fragment encroaching on the joint surface may change the joint axis to an extent which causes deviation of the articular surface and thus loss of function. It is therefore more important to restore joint fragments to their normal axis than it is to restore shaft fragments. The tilting of the joint induced by one short side or surface must be avoided. In shaft fractures we look for compensatory bone changes in accordance with Wolff's law, but about joints these favorable changes do not appear. Anatomical reposition may not be secured in shaft fractures and in most cases is really not sought, but functional reduction is desired. We may then conclude with Ashhurst[1] that if open treatment is required for old diaphyseal fracture, it is more often because of *non-union* or of concurrent lesion of the soft parts than because of rare malunion which in time cares for itself. Likewise many fractures have to be treated in accordance with general anatomical knowledge. We attempt to bring one fragment which we can control in line with another which responds to the pull of muscles and is displaced. Fractures of the upper third of the femur and the surgical neck of the humerus are cared for on the basis of muscle pull on the upper fragment which rotate, abduct, and elevate it. However, we cannot state positively what position will be required, because anatomical laws do not apply to many fractures. Some muscle attachments are torn out, other muscles may be in spastic contraction, and those still attached may produce pulls or cause distortions contrary to anatomical expectation.

Deformity and disability are not always the result of insufficient reduction. Striking examples of these facts in spite of a seemingly perfect reduction are seen in wrist-bone fractures and Colles's fractures, which may be very accurately replaced and yet the crushing of the cancellous bone of the radius may produce permanent shortening of the bone which no manipulation will restore. Similarly in other fractures, even when anatomical reduction is made by operation, permanent bone changes may occur. The trauma causing the fracture may induce periosseous changes which involve joint surfaces or surrounding tendons and muscles and which lead to a permanent impairment of function.

When treating fractures we are apt to overlook lesions of the soft parts. They are always present and are frequent cause of later disability. In open fractures we do not neglect them, because we fear infection more than any other thing, and the bone lesion becomes secondary. These disabilities from lesions of the soft parts can be forestalled in treatment if we insist on early active movements and functional use when the bone union will tolerate it. Massage, including effleurage and petrissage, should be used from the first to reduce edema and swelling and to prepare neighboring joints for early functionating.

It is necessary to say, in view of the development of common use,

[1] Am. Jour. Surg., New York, 1915, xxix, 114.

that the Roentgen rays should be used in every traumatic case where fracture or dislocation is suspected. This is possible even in remote rural districts where electric current may be furnished by a storage battery, or from an automobile. From the medicolegal standpoint a roentgenogram is of the greatest weight. The influence on treatment is also far reaching. Study of Roentgen pictures taken for injury of the upper end of the femur reveals many surprising points in the bone pathology, and if a general rule is followed in treatment by abduction or elevation, the surgeon will frequently cause increased displacement of split or broken-off lesser trochanters and other parts. To treat fracture intelligently, we should know the relative position of the fragments in every case both before and after attempts at reduction. This knowledge may lead to repeated attempts to better the displacement and bring about a final result much more satisfactory to the patient and surgeon than that obtained by unchecked methods. Estes[1] says that accurate adjustment of fragments was never obtained in fractures treated by older methods. This is not so much an argument in favor of operative reduction as it is of checking attempts at reduction by the roentgenogram until the desired position is secured, or the case enters the operative class.

The use of the fluoroscope to control reduction probably has some future, especially in hospital work. There are limitations to it that everyone who has attempted to use it realizes. It is difficult to see distinctly small fragments near joints, and when a reduction is made without a fracture table or other mechanical apparatus there is no surety that the reduction gained is held during the application of the splints. Fluoroscopic examination through plaster casts is unsatisfactory. In the chapter on Operative Treatment the method of pinning fractures through a cannula with the fluoroscope is mentioned.

Means of Reduction.—*Anesthesia.*—The need of anesthesia must be decided by the surgeon before reduction is attempted. It is wiser to use an anesthetic to obtain an early complete reduction than it is to cause the patient pain and fear by efforts of reduction without it. Repeated attempts cause increased local infiltration and edema. There is subfascial swelling, which shortens and broadens the limb and defeats efforts at lengthening by traction to overcome deformity. When the limb is pulled, the capacity of the fascial envelope is reduced, there is greater pressure within it, and the subsequent pain induces tonic muscle contraction. The circulation may also be interfered with, so that it is better to let all local swelling subside if repeated attempts at reduction are anticipated, or an anesthetic should be used early. Satisfactory early reductions minimize pain, they favor the best circulation, and there is no muscle spasm and contracture to be combated as in late setting.

Anesthesia may be general or local. Nitrous oxide gas is often sufficient to produce relaxation and freedom from pain in non-alcoholic

[1] Am. Jour. of Surg., xxviii, No. 1.

patients. The ether rausch is very helpful, and surgical anesthesia with ether is necessary when mechanical traction and traction-fixation are to be applied. Local anesthesia was used in America a quarter of a century ago by Conway. Quenu and Braun[1] inject suitable quantities of novocain by means of long thin needles inserted at the fragment ends. This has its greatest value in the leg or about the ankle. Dollinger[2] describes a reduction of a fracture of both bones of the leg, after the inducing in this manner of a zone of local anesthesia proximal to the fracture. For upper arm fractures the best procedure is a blocking of the brachial plexus. Kulenkampff[3] has described this method, with the needle inserted above the clavicle.

The means of reduction are direct pressure, rotation, lateral pressure, and mechanical traction. Direct pressure may be sufficient to cause reduction in buckling or green-stick fractures, or in oblique fractures with little displacement. It may be applied for a short time to cause reduction followed by fixation in an external splint, or it may be applied continuously over a period of time by means of pads.

The surgeon must make use of general pathological bone knowledge and experience in setting fractures. When the roentgenogram is to be had it is of assistance, but practically the adept makes out the type and extent of the displacement even in those bones which are covered by thick, soft parts. Delicate manipulation, close observation, and measurements indicate the type of displacement—whether it is shortening, angular, or rotatory. It is impossible to expect anatomical reposition in any great percentage of cases reduced blindly, even though anatomical knowledge of the highest grade be used. Even if difficult to obtain, a roentgenogram should be used after the best possible reduction has been performed. Glaring faults are often revealed.

The Supreme Court of Washington has recently decided a case[4] abstracted in the *Journal of the American Medical Association*.[5] The plaintiff was injured in a coasting accident which fractured her leg above the ankle, and also fractured the femur above the knee. There was an open wound which became infected. The attending physician did not recognize the femur fracture until a roentgenogram was made two weeks after the leg fracture was set and put in a plaster cast. She was awarded $7305 damages. On appeal it was argued that the trial court had erred in allowing evidence to be received tending to show that the defendant was negligent because a roentgenogram was not taken sooner after the accident, etc. The Supreme Court held that this was all right but that because the surgeon cannot be held to answer for the suffering caused by the original injury but only for the suffering caused by his own neglect, the damages awarded

[1] Deutsch. med. Wchnschr., 1913, p. 17.
[2] Zentralbl.. f. die Gesamte Chir. u. ihre Grenzgeb., 1913, Bd. i, 175, and Zentralbl. f. Chir., 1913, p. 763.
[3] Zentralbl. f. Chir., 1911, p. 1337.
[4] Cranford *vs.* O'Shea (Wash.) 145, Pac. R., 579.
[5] May 8, 1915, lxiv, 1606.

were excessive, and $2000 was cut off the amount. This remission was in accordance with the law's demand that the plaintiff bear her share of the misfortune which chance had brought upon the parties. If the limb is corrected to a position of normal axis, and the principal points of displacement are straightened in a manner satisfactory to the eye and palpating fingers, the surgeon may anticipate a favorable outcome. Overcoming of the effect of gravity and of contracted muscles, which cause most of the displacement, can be accomplished through the relaxation of certain groups by means of flexion, and advantage must be taken of these positions while the general axis is maintained. Sir Astley Cooper and others taught the value of maximal relaxation of a limb in semiflexion, and this position in treatment has lately been revived by Zuppinger. The proper support of the limb in a suitable fixation dressing is a part of this treatment, but some cases which are treated intelligently and give no outward evidence of being unusual, fail to respond in the normal way, and complications ensue. This course of events is beyond the skill or knowledge of the surgeon to prognosticate, and such results are as common in faithfully attended instances as in the neglected ones. Undoubtedly the causes of non-union, for example, lie within the patient in the majority of cases and are not much influenced by external treatment in the period demanded for ordinary bone union.

The limitations of treatment and the prognosis of different fractures are indicated under the heading of each bone.

Traction.—Traction may be divided into (*a*) immediate traction by a direct powerful pull and (*b*) prolonged traction.

(*a*) *Immediate Traction.*—Immediate traction may be applied manually by the surgeon and his assistants pulling and counter-pulling, grasping the limb in their hands. Harness or a bandage may be arranged on the extremity of a limb whereby the surgeon may apply his body weight for securing traction. In the reduction of fractures about joints such as the malleolar fractures at the ankle, stresses and pulls are exerted by traction on muscles and ligaments. This principle is particularly useful in epiphyseal separations. The best method of applying traction is by mechanical means. There are two general forms of mechanical extension in use. Without this form of extension many fractures cannot be satisfactorily reduced; with it many cases which seem to lie wholly within the operative class will be removed to the non-operative. With mechanical extension applied for a few moments more direct force of traction can be applied on the fracture than several assistants can furnish by manual pull. I recall seeing Dr. Joseph Blake at the Presbyterian Hospital in New York some years ago. He with six assistants was trying to lengthen a leg which had a fractured femur. An open operation had been performed, and the bone ends were freed, but after a half-hour of tugging, which disarranged the operative field completely, I doubt if they had gained a quarter of an inch in length. Extension applied by canvas or other swathes directly on the end of open fragments (Edwin Martin) or

Another extension or traction apparatus is the Hawley fracture table, which I have been using continuously for some time. This table is not portable, but in addition to offering mechanical traction

FIG. 26.—Patient supported on table ready for application of body and leg encasement. Note the pelvic support, the bandage support of the thighs and the attachment of the feet for traction.

for leg and thigh fractures and their operative or non-operative fixation, it can be used for applying orthopedic plaster casts or dressings

FIG. 27.—End view of a patient on the table with legs abducted and extended.

on arms and shoulders. It also permits traction on legs in part flexion and saves time in application of casts, and reduces the number of assistants necessary (Figs. 24 to 32).

While traction is in force the surgeon can correct lateral displacement by direct pressure. In oblique or transverse serrated fractures advantage may be taken of rough edges or points which interlock and

Fig. 28.—Method of applying traction and counter-traction with extension before applying plaster.

hold reduction. Penetration of muscles by sharp fragments, a common occurrence in the lower part of the femur and the upper part of the

Fig. 29.—Detail of cuff applied about the ankle. This is used to take up the force of traction.

humerus, cannot be reduced by direct traction. The bone fragment must be disengaged from the muscle. This is done by manipulation which seeks to relax fully the muscles concerned. In the thigh, the

hip and knee are flexed to relax the quadriceps muscle and pull it down over the sharp point of the upper fragment. When the bone is freed

FIG. 30.—Foot applied to rest and traction tightened. After the plaster hardens the metal foot piece is lifted out of position.

the distal portion of the limb is swung out into line with the upper part, and traction is started to lengthen the contraction and bring

FIG. 31.—Method of using the table to apply arm traction.

the fractured surfaces into apposition. If manipulation fails, open operation is indicated.

(*b*) *Prolonged Traction.*—Prolonged traction is applied by non-operative and by operative means. The non-operative types are Buck's Extension, or adhesive extensions, which depend on gravity or weights hung on a pulley. Examples of these are the Hodgen splint for the leg, the Thomas splints and harness extension, as for fracture of the spine, and plaster casts with provision for extension on imbedded metal rods (Hackenbruch's). Bardenheuer and the Cologne school have worked out an elaborate system of adhesive-plaster extension for fractures.

Grune, from Bardenheuer's clinic,[1] has reported 41 cases of fracture of the femoral neck treated by extension, in only 3 of which was

Fig. 32.—Body and arm plaster encasement applied while the patient lay on the table.

the shortening equal to ½ to 1 cm. This treatment requires much care in its course.

The operative tractions are Codivilla's and Steinmann's nail extension and Ransohoff's ice-tong modification. (See Operative Treatment for Fractures of the Femur.)

Traction which is continued causes stretching of joint ligaments and fascial sheaths as well as of the contracted muscles. Which type of structure yields first is difficult to say, but clinically we know that muscles gradually tire out and elongate so that length of a limb can be gained after a long period of time. It is also a question as to how much reposition of bone is gained by prolonged traction. I believe that the ordinary Buck's extension, used as it frequently is

[1] Deut. Ztschr. f. Chir., 1913, p. 81.

with the leg bound to a Liston splint or lying in a fracture box or on the bed, has little real extension pull. For that reason the Hodgen suspended splint which relies on gravity for a steady pull is much better in thigh fractures. Ordinarily the weight hung on to a Buck's extension is too small, and the leg friction on the bed surface or the mal-application of the pulleys and ropes cuts down the real force exerted. A simple universal extension apparatus has been devised by Swenson[1] which obviates these difficulties.

The use of Buck's extension is so universal with the profession that its faults compared with the suspension principle of the neglected Hodgen splint have been overlooked. Brady[2] has called attention to the advantages of this type of suspension in fracture of the femur. Hodgen's splint (see Fig. 33) offers an unremitting extension assured by the elasticity in the arrangement of the extensive force, whereas the Buck's extension is a dead pull of an unestimated force because of the unknown factor of friction. With the Buck dressing two fixed points are necessary, one at the patient's pelvis and the other at the pulley, but the Hodgen suspension requires but one fixed point, the limb's own weight taking the place of the pulling weights in Buck's. There are other advantages which can be credited to the Hodgen extension: the limb lies in physiological flexion in accordance with Zuppinger's teaching. The hamstring and psoas muscles are relaxed and do not obstruct reduction. The pull on the lower fragment can be accurately estimated by means of a spring scale included in the suspending cord. The patient can turn in bed, sit up and assist himself in many ways without changing the position of fragments, relaxing the tension, or jerking the limb, because the motions occur at the hip-joint and not at the fracture site. Although the patient's movements while in Buck's extension seem to have no untoward effect on bone healing, they are painful and tend to permit recurrence of the deformity.

Hodgen Splint Construction.—The frame is made of iron wire the thickeness of a lead-pencil, its length being from 32 to 38 inches measured from the perineum to a point 4 inches beyond the sole. The base breadth is 4 inches with a little lateral spreading at the malleoli. A picture of Brady's modification is given. He solders six upright rings on the frame and at the base fixes two upright wire posts or loops 2 inches high through which the extension straps pass. At the free end is a wire wicket which locks on after application to prevent the splint from spreading under the weight of the limb. The hammock in which the leg lies is made of heavy muslin in which are cut buttonholes corresponding to the six rings and the two upright wire loops. The hammock is loose enough to allow for slack which gives room for the calf and heel. It is pinned to the frame with safety pins. From each supporting ring a waxed twine is attached and run to a common supporting point above the foot, where they are looped over the hook of the spring scale. Each supporting twine is fastened

[1] Surg., Gynec. and Obst., August, 1914, p. 114.
[2] Internat. Clin., Philadelphia, 1915, 25 S. i, 191.

by means of a tent block. To the handle of the spring scale a piece of sash cord is fastened, and this cord is run up over a pulley in the ceiling and back, fastened by being knotted in another tent block.

Method of Application of Hodgen's Extension.—Two-inch adhesive plaster is applied to the shaved leg as for Buck's extension, except that two separate pieces are used instead of a long loop. Beyond

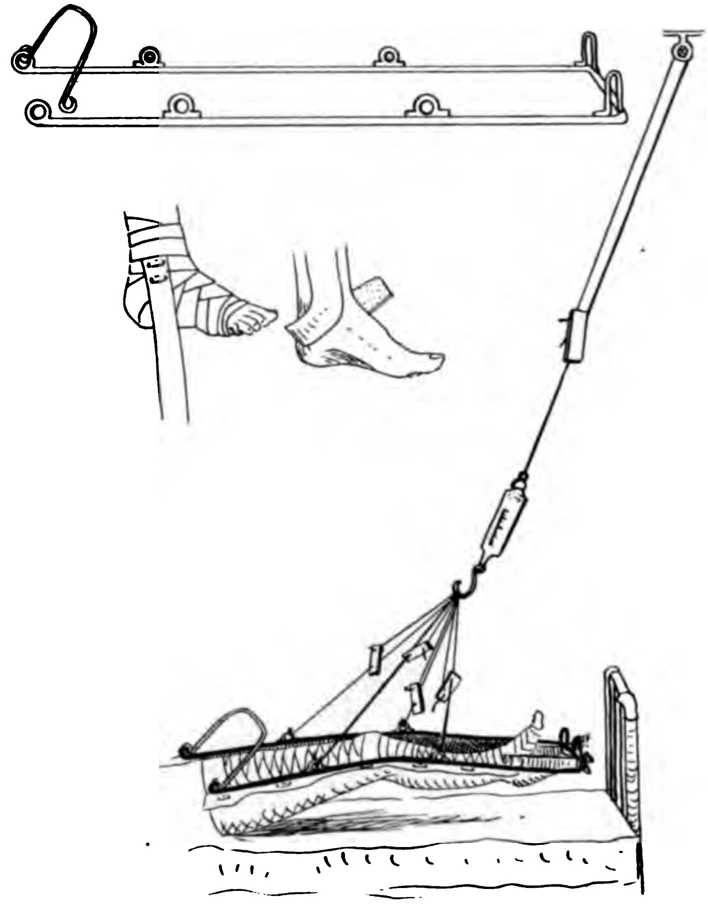

FIG. 33.—Illustration of the Hodgen splint for fracture of the thigh. Adapted from International Clinics, 1915, 25th series, vol. i. Note the bare splint, the method of applying extension at the ankle and the completed and suspended splint holding leg.

each malleolus is left free a six-inch extension, which is doubled back on itself to make a three-inch tab with no adhesive surface exposed. The upper end of the plaster strips lies at a level just below the fracture site. On to each adhesive tab is pinned a strip of muslin a foot and a half long. After this preparation an assistant lifts and moderately extends the limb at the ankle, the frame is slipped under with the

free end at the perineum and the wicket is locked in place. The two muslin strips at the ankle are drawn through the wire loops at the end of the splint and tied. Leg contour is allowed for by adjusting the pins which hold the muslin hammock, the waxed cords are attached and adjusted by the tent blocks, and the limb is lifted just free from the bed. The spring scale indicates the weight of the limb in this condition. The leg is then hauled up free from the bed and the frame is bent about 20 degrees at the knee, after which the cords are again adjusted until all pull smoothly, with the buttock raised enough so that the hand can sweep freely beneath it. With this corrected position the spring scale will read 5 to 8 pounds more weight than the simple weight of the limb, the extra weight representing the actual pull on the leg. The bend in the frame is meant to allow for the normal physiological semiflexion of the leg. Abduction can be obtained by locating the pulley plane to one side, or by moving the bed. With young patients it is necessary to place a small sand-bag on the frame to give additional weight for overcoming the shortening, because the leg's weight is insufficient in itself to overpower the resistance of its strong muscles. A similar increase of pull is given by the moving of the bed farther away from the pulley. With obese patients, when the leg is too heavy and gives too much pull by its own weight, the bed is drawn more directly under the pulley to lessen the stress.

After-treatment.—Pressure on the heel must be guarded against, and the hammock can be readjusted to obtain comfort. No sand-bags or coaptation splints are needed. A minimum excess of four pounds over the limb weight is required on the spring scale. Brady states that the limb should rest $\frac{2}{3}$ below and $\frac{1}{3}$ above the level of the arm, and that the adhesive must pull perfectly straight. Inversion or eversion are gradually overcome as the muscles tire, so that by the time the two legs are of equal length eversion has disappeared. In the early stage of treatment marked eversion can be corrected through tightening of the outer pair of supporting cords. The thigh muscles, helped by the uninterrupted traction, act as a splint, and within eight to fourteen days the leg has straightened out and reached its full length. When this condition is established all dressings are removed, the leg is massaged and later put in a light circular cast or moulded splint, and crutches are furnished. Fractures of the neck should have at least six weeks' extension, followed by a cast and ambulatory treatment.

The Thomas Splint.—The Thomas splint rigged for extension from the bottom of the frame with its *counter-extension by the padded ring* around the thigh and buttock, offers real extension. Mr. Robert Jones related to me some time ago a case of open fracture of the lower end of the femur in which the lower fragment was flexed by the calf muscles and came to lie sticking out of the wound. Treatment was started in a Thomas's splint with extension and counter-extension, and he assured me that his house surgeon was able to notice from day to day the final complete alignment of this flexed lower fragment with the rest of the shaft.

The development of the distraction of nail extension is interesting. In 1903 Codivilla first applied a cast to a fractured leg from the toes to the pelvis. The next day he cut the cast circularly, dividing it about the middle of the thigh. By means of strong traction the severed surfaces of the cast were separated, and the space created was filled in with fresh plaster of Paris, traction being maintained until setting. This procedure could be repeated. The method was abandoned because decubitus sore developed about the tuber ischii and the dorsum of the foot. To avoid these pressure ulcers Codivilla left the foot and ankle free and put two lateral irons into the lower end of the cast. The free ends of the irons ran down beside the ankle and were fitted by means of holes over a nail driven through the os calcis. Pads were applied over the ischium, and decubitus was avoided. Steinmann, in 1907, discarded the cast altogether and applied traction directly to the nail ends passing through the os calcis.

In von Eiselsberg's clinic in 1901 Käfer, in putting a cast on a leg, incorporated a turnbuckle on either side. The cast was cut and the halves distracted by turning up the turnbuckles. Hackenbruch improved this method by putting a ball-and-socket joint at either end of the turnbuckle where it joined onto the imbedded plate. By distraction, shortening in the leg was overcome inside of forty-eight hours; then the four ball-and-socket joints were cautiously loosened, and any lateral displacement was corrected. The reduction was checked by roentgenograms, and when a satisfactory adjustment was reached all points were firmly fastened and the patient was allowed to walk on the leg thus held in perfect position.[1] Patterson's method[2] is the same. Gerster[3] has adopted Steinmann's nail extension as a part of a splint for maintaining extension during transportation. To avoid the pressure on the ischium he used an upper padded ring made in two halves hinged behind and locking in front. The splint was composed of long bars of hard wood, which do not interfere with roentgenograms, and the lower end was formed by a stirrup with slotted bars permitting adjustment by thumb-screws. Tongs were applied to the nail, and a cross bar held them up, while a rope attached them to the distal end of the splint.

Fixation.—Fixation purposes to maintain the reduction obtained and to prevent subsequent displacement of the fragments. To accomplish this result fixation must overcome muscular contraction, ligamentous pull and gravity, should relieve pain, and should furnish security from slight external disturbances and subjective movements. Some of these indications are met by the traction and reduction methods which may also be considered fixation treatment. There are also certain accessory procedures which are used as routine in fracture treatment. In spinal injuries we always employ air or water beds

[1] Hackenbruch's references, Ztschr. f. ärztl. Fortbild., 1913, p. 28; Zentralbl. f. Chir., 1913, p. 605; Deutsch. Ztschr. f. Chir., Bd. cxxii, 464.
[2] Am. Jour. Orthop. Surg., 1913, p. 649.
[3] Am Jour. Surg., xxviii, No. 31; and Am. Jour. Med. Sci., August, 1913, p. 157.

to give uniform pressure on the parts compressed by long periods of recumbency, and in leg fractures which are kept in bed, a fracture bed is made. A fracture bed consists of one or more flat boards, of lengths equal to the bed width, passed across the long axis beneath the mattress to furnish a flat resisting surface for the splint to lie on. These boards prevent sagging and bending of the bed surface.

Regardless of the character of dressing used on a limb after fracture the most important feature in the first few days is the condition of the circulation in the part. In order to guard against interference with circulation no splint should be applied tightly at any time, especially soon after an injury when the swelling which follows all fractures has not reached a maximum. Slight external pressure, additional to the internal pressure in the limb, may completely interfere with blood supply, resulting in local pressure necrosis or ischemia of the whole limb with subsequent contracture. This danger is avoided by the employment of loose cotton padding or sheet wadding about the limb. No limb should be bandaged by means of a roller bandage beneath a splint. Fingers and toes should be exposed and watched for evidence of imperfect circulation. It is neither wise nor customary to apply circular casts or tightly fitting splints to a fresh fracture even if it has little displacement, because a mild local fracture reaction of extravasation and swelling is expected. Fractures of the arms and legs are best cared for by complete rest in bed at first, in temporary splints, until swelling has disappeared. The probable formation of blebs, with the necessity for their aseptic evacuation, and the care of abrasions and small cuts in the skin also militate against early permanent dressing fixation, but not against early reduction if it can be held. If the condition of a part warrants treatment in a permanent dressing before these skin lesions are completely healed, they can be allowed for by suitable openings.

Types of Fixation Dressings and Splints.—Coaptation splints are composed of wood, cardboard, and leather, in narrow strips. Malleable iron, zinc strips, and aluminum, are also used. These splints are applied to limbs in fracture of the shafts of bone and may be used alone or in conjunction with extension or other forms of dressing. They are laid on in series, like a bundle of faggots, encircling the limb at the fracture site, being bound on by bandage or tape. Strips of wood not much larger than the common wooden tongue depressors are excellent coaptation splints. They can be sewed into muslin bands to make a sheet. An amount necessary to encircle the part is cut off. The malleable iron splints can be moulded by the surgeon's hands. Robert Jones prepares them in many sizes for adult and children's use. They are shellacked and padded on one surface with a coarse felt. Ordinarily coaptation splints are not applied on a bare skin; cotton or sheet wadding is put beneath them.

Wooden splints are used constantly. Any piece of wood from the size of a small wooden tongue depressor for a finger to a 2 x 4 scantling is used to immobilize broken bones. They are applied

laterally or posteriorly or in combination as on each side of the forearm. The wood itself is padded over with cotton wadding bandaged on. The limb is further protected by cotton or wadding at bony points and depressions. This padding is placed *around* the joints, not over them; then the padded splint is bound against the limb by bandages or adhesive plaster.

Fracture boxes are wooden boxes inclosed on three sides and are used as temporary splints. Some have sides which are hinged and held by buttons or hooks, so that the lateral aspect of a leg can be inspected by the opening of one side, without displacement of the entire limb. These boxes are partly filled with cotton, and the leg is slipped into them and arranged in a comfortable position, with excess padding beneath the heel and knee. The foot is straightened and is held by a turn of bandage, a wad of cotton, or a small narrow sand-bag. This splint permits the application of an ice-bag and is often used for cases of great swelling and ecchymoses with bleb formation until permanent reduction and fixation are safe. Shallow moulded metal gutters with a right angle foot-piece have partly taken the place of fracture boxes because they are lighter and occupy less space. They will never completely usurp the place of the fracture box, because the box is easily and cheaply made anywhere and a leg can be laid in it on a soft cushion, whereas the leg must be bandaged to the metal splint and danger of pressure is thereby incurred. The box has also greater stability of position.

Other wooden splints used are double inclined planes which are adjustable to different angles and railroad splints, or the Volkmann sliding splint. These hold the leg laterally in axis alignment and permit the application of elastic or weight extension. A good railroad splint which provides for elevation of the leg, knee flexion, and application of extension, is a very valuable dressing for hospital use. It has great stability. Wire splints of two kinds are serviceable. Coarse-meshed galvanized wire is often used as an outside splint around dressings after bone operations. It is light, easily removed, and stiff enough to prevent dislocation of fractured ends. The second class of wire splints is composed of wire gutters, coaptation, and other extensive leg splints. Some of these are adjustable for different angulation of a limb, or for various degrees of abduction and adduction of the foot. They come in different sizes and can be moulded by the surgeon's hands to fit. Their advantage is lightness, ventilation, cleanliness, and durability. They are bound on the padded limb by bandage or adhesive plaster. Page[1] described aluminum skeleton splints for both the leg and arm. The leg splint is like the Hodgen and the arm splint is a lateral skeleton which permits some extension on the forearm.

Suspended splints are either anterior or posterior. The Hodgen's splint, which is posterior, has been described. The best known anterior splint is that of Nathan Smith. This is made of two parallel iron rods

[1] Brit. Med. Jour., May 15, 1915, No. 2837.

joined by three or four curved cross rods. The splint is bent in the form of semiflexion of the leg and the leg is attached to it by bandaging or straps. The leg is swung up by rope to a pulley. It is used in fractures of the femur. Sometimes such a device is imbedded in the anterior surface of a plaster encasement of the leg. Parts are cut out of the plaster after it hardens to permit dressing of an open wound or ventilation. This splint is little used now, other methods of suspension or extension taking its place.

The two most important splints for extension and immobilization of the leg are the Thomas and the Englemann splints. The Thomas splint has been described previously. It is strong, durable, and very efficient, especially when combined with elastic extension at its lower end by Buck's adhesive method. The Englemann splint is really a modification of the Thomas. It is composed of two metal strips with a ring at the top to fit over the thigh and against the tuber ischii. The lower end is attached to a nail driven through the sole of the shoe, and the whole is adjustable to extension by means of the sliding character of the side rods, which can be fastened by thumb-screws. It is not as valuable a splint as the Thomas, which can be combined with a body portion to give abduction of one or both limbs, and on which children can be placed and moved about at ease. (See Ambulatory Splints.)

Plaster of Paris.—Plaster is used in two forms, as moulded splints and as plaster encasements. Many surgeons use it exclusively in treatment of fractures, both as temporary and permanent dressings. Moulded splints are seldom made of leather. Plaster is cheaper and can be moulded to fit any form or angle. Moulded splints are made either by using coarse meshed gauze pads cut out in the required shape and soaked in a plaster cream, or by direct application of plaster bandage to a limb without circular encasement. These wet plaster masses are bound on the padded part by means of an outside bandage, and the limb is held in the position required until the plaster has set. After hardening the splint can be quickly removed if pressure symptoms appear. The best method is to take the exact measurement of length of splint desired, and use broad plaster bandages. They are run out on a glass or slightly greased surface layer after layer in the desired dimensions, and when the mass is thick enough it is applied over the limb and bound on to set. This method saves plaster and time, especially when the patient is under anesthesia, or after operative procedure. One assistant can be laying out the moulded splint while the surgeon is dressing and padding the wound or making a reduction. Moulded splints may be anterior, lateral, or posterior, and one or two may be applied on the same limb. (See picture of moulded splint used in ankle fractures.)

Plaster encasement or a cast as it is called, is applied by turns of wet plaster bandages, weak points being strengthened by longitudinal folds. This type of dressing should never be applied to a fresh fracture even when the displacement is *nil.* It is impossible to foresee how

much swelling, or what complications involving the skin surface, as blebs or infections, or what circulatory changes will follow. Small cuts or abrasions on the skin may become the source of serious infections possibly gangrenous in type, and if the limb is enclosed in a solid plaster mass, no direct evidence of the progress of these conditions can be had. Circular encasements should be applied only to cases in which the primary swelling has disappeared and the skin condition is satisfactory. It is the best practice to imbed in each cast a Gigli saw, so that it can be split longitudinally as soon as it hardens. This split permits some swelling within its confines and prepares it for immediate removal in case of obstruction to the circulation, or pain. If these measures are considered necessary by surgeons in hospital practice where patients are under constant surveillance, can any one doubt the necessity of this step under other conditions where the doctor does not see the patient for hours or days after the dressing is applied.

The technic of application is simple. The limb is carefully sponged off with alcohol, and small abrasions are touched with tincture of iodine and covered with sterile gauze. Cotton padding or wadding is applied loosely over the skin surface, the formation of wrinkles being avoided. No bandages are applied beneath casts. Bony prominences can be protected by extra cotton applied *around* them. The plaster bandages are placed *end up* in warm water, which must be deep enough to cover them entirely. This position of the bandage allows the water to permeate it quickly and favors a rapid driving out of the air bubbles through the open bandage end. When removed from the water they are not wrung or milked to force out all the plaster cream they contain but are given *one* squeeze by a firmly grasping hand. If quick setting is desired salt or powdered alum may be added to the water.

The bandages are applied smoothly and are never reversed. Longitudinal folds are valuable for strengthening as suggested. The cotton padding is left long beyond the area of plaster application and as the encasement is finished this extra wadding is turned back and held by a turn or two of the plaster bandage. This gives a finished effect and a soft non-irritating edge. To smooth the surface, plaster cream may be applied, or the surface may be rubbed off with a gauze sponge soaked in alcohol. Most surgeons wear rubber gloves in this work to protect their hands.

Bands of metal or wood may be imbedded in the plaster to strengthen it. The casts may be interrupted, connected by bowed pieces of iron which are imbedded in the plaster above and below an exposed area. Windows are often cut out over areas of abrasion or wounds. These should be removed by a sharp short-bladed knife before the plaster has completely set. When body casts are applied it is advisable to have a Bradford frame ready on which to place the patient.

Ambulatory Splints.—Ambulatory treatment of fractures has come to mean two different things. The patient may be put in a permanent dressing and allowed to be up and around even if a leg is involved. He uses crutches without bearing weight on the fracture and is con-

sidered to be ambulatory. Ambulatory treatment really means that in fracture of the lower limb some rigid splint is applied which permits the patient to walk with crutch or cane at once, using the injured leg to bear weight. It is asserted of this type of treatment that it favors bony union, it shortens time of disability and hospital stay, it lessens danger of hypostatic lung congestion and other complications.

Ambulatory splints are made of plaster of Paris or metal or a combination of both. A solid plaster encasement which holds the fracture in reduction can be strengthened at the foot end by the imbedding of an iron stirrup. The shoe of the well foot is raised to a corresponding height by an extra sole, and the patient is permitted to walk with crutches. If an iron projection is not used, the plaster quickly wears away and breaks. Other ambulatory splints are made of metal padded with leather and pneumatic bands. These embrace the trunk and the injured limb and provide for extension. In cases of imperative ambulatory treatment or non-union which can be stimulated to repair by the irritation of walking, these splints are valuable. They are expensive and cumbersome. Some dealers rent them for the period of immobilization demanded.

Dollinger has been an advocate of ambulatory treatment since 1911. Since that time many different types of splints have appeared. All take fixed bony points such as the tuberosity of the ischium and the femoral condyles for pressure. They are all thoroughly padded. Patients are encouraged to walk from the first. Többen[1] has devised an ambulatory dressing with extension. He used a firm felt anklet with eyelets at the lower margin. This is fitted snugly over the malleoli and is cut open behind to avoid pressure on the calcaneus tendon. A plaster cast is applied from just below the knee to within two inches of the ankle. An iron stirrup which extends well below the heel is incorporated in the plaster cast. One inch proximal to the stirrup cross piece is a second iron cross bar, which has a thumb-screw in its center. From the eyelets of the anklet strong laces extend to the thumb-screw, which when tightened caused traction on the leg. Jaboulay has a similar apparatus in which traction is made on a shoe plate instead of an anklet.[2] Giaquinta[3] advocates ambulant treatment with extension. The ambulant treatment of Hackenbruch[4] is applied in fractures of both bones of the leg. A plaster encasement is put on the leg from below the knee to the ankle. The areas around the patella and knee and the ankle are very thickly padded. The day after the application, the cast is cut over the site of fracture and Hackenbruch's clamps are inserted. By means of these adjustable clamps powerful extension is applied, which is increased daily until a satisfactory position is reached, whereupon the clamps are set and the patient is allowed to walk. The knee is nearly always quite movable, the ankle has slight motion, and the foot is free. Treatment with

[1] Zentralbl. f. Chir., 1913, p. 996.
[2] Patel, Progres méd., 1913, p. 286.
[3] Gaz. degli osp. e delle Chir., 1913, p. 13.
[4] Lancet, March 14, 1914, p. 744.

this extension obtains complete lengthening in a week, according to its inventor, and the patient becomes ambulatory in the second week, the cast being left on four weeks or more.

Massage and Allied Treatment.—Massage and passive motion are decidedly different measures and have different effects on fracture results. There is almost universal agreement that nothing but good results follow early and gentle massage after fracture. Lucas-Championnière is the most extreme advocate of massage, which he combines with movements and passive motions of the neighboring joints throughout the whole course of repair of fracture. The massage should *not include passive motion* of the fracture site. When the massage is given, it is given to relieve swelling and edema, to promote freer circulation and consequently reduce pain, and to hasten repair of bone. It is done with the finger tips alone in recent fracture, the operator rubbing in gentle steady strokes always toward the body. Early passive motion on the other hand is distinctly harmful. Passive movements which produce a rebellious reaction of pain and swelling in the fracture site or joint are pernicious. They cause disturbance of the uniting bone fragments, they lead to fresh plastic effusion, and result in excessive callus and connective-tissue formation. The ultimate results are increased involvement of the soft parts about the fracture, or an unnecessary stiffness of joints involved. The elbow-joint is the one most frequently harmed by passive movements. (See Treatment of Elbow Fractures.) These injuries should not be given movement, except at the one time when reduction is performed. The joint should be settled in the position necessary for a perfect reduction of fragments and then should be left undisturbed, until the surgeon is satisfied that bone union will not be harmed by movement. This statement can be applied to all joint fractures equally well. In fractures of the anatomical neck of the humerus light massage may be practised from the time of injury, but no passive movement should be permitted within two or three weeks, and then all motions should be below the threshold of pain production. If this rule is insisted on, motion usually becomes very satisfactory after six weeks. Hitzrot[1] gave end-results in 139 cases of upper humerus fractures treated by massage and movements every other day ten days after injury, with all splints removed after the third week. All but 2 of these cases lost hyperabduction of 5 per cent. or more, the hyperabduction being measured by the scapular movement from the midline of the back compared to the normal side.

Forcible passive movement should never be started after fracture near or into a joint in the hope of restoring normal movement. When this is repeatedly performed with painful results or under anesthesia it leads to a stiffer condition in the joint. Even active motion must be inhibited when it causes the slightest pain.

After the removal of splints or permanent dressings and change

[1] Ann. Surg., lv, 348.

of position by the patient, there is usually some acute swelling and edema of the peripheral part of the limb. For this condition a slightly deeper massage may be given, but the patient must be guarded against sudden movements which throw extra stress on the recently healed bone. This secondary massage promotes earlier return of function and lessens muscular atrophy. Attention is directed to the cases of fracture of the tibia at the site of removal of bone splints. One occurred nine months after removal of the splint from the tibial crest when the patient put sudden excess strain on the leg in attempting to board a street car. These legs had been partly weakened by the removal of the bone peg. Gillette has inveighed against passive motion in injured joints[1] recalling the fact that human joints exhibit the highest form of mechanical pulley and leverage action. They are unlike manufactured mechanical joints, in that they possess an ability for self-repair and lubrication and do not wear out. After injury or fracture into them, mechanical obstruction or intercurrent disease must be overcome before motion is attempted by force or otherwise.

Treatment of fracture must primarily aim at immobilization of bone fragments, but not of all muscles and tendons in the vicinity, if they can be used actively *without* pain or can be delicately massaged. In wrist and arm fracture constant early finger movements are urged unless pain results. After the fourth decade in life there is greater tendency than earlier to edema, adhesions, osteo-arthritis and thrombosis after fracture, and consequently the surgeon's efforts must be directed toward an early anatomical reduction. This is more important in the leg than the upper extremity, and more disability in walking arises from stiff and subankylosed ankles and improper leg axis than from shortening.

Other accessory treatment after fracture consists in hydrotherapy of hot and cold baths, electricity, and baking, all looking toward improvement of circulation and restoration of muscle tone. Persistent active muscle movement is the best adjunct.

The Committee of the British Medical Association in 1912 made a painstaking study of 2940 cases of fracture, of which 208 were operated cases.

They desired to weigh the value of operative and non-operative treatment. The operated cases were selected from the clinics of those surgeons who were skilled in and best equipped for this work, and the non-operated cases were taken from the services of a representative list of general practitioners. The good results asserted in operated cases were 79 per cent. as compared with 70 per cent. in non-operated. This report, as well as that of the Committee of the American Surgical Association in 1913, is referred to later under the heading of Operative Treatment. Estes[2] has rearranged the conclusions of the American committee:

[1] Jour. Am. Med. Assn., October 17, 1914.
[2] Am. Jour. Surg., xxviii, No. 1.

1. Although functional result may be good with indifferent anatomical result, the most certain way to obtain good functional result is to secure good anatomical result.

2. In nearly all age groups operated cases show a higher percentage of good results than non-operated cases.

3. No method which does not promise good anatomical result can be chosen.

4. The operation should be performed as soon after fracture as is consistent with best results.

5. The mortality of operative interference is so small that it has little weight.

6. Operative interference requires special skill, etc.

7. Because many surgeons and practitioners are unable to avail themselves of the operative methods, the non-operative procedures are likely to remain more safe and serviceable for some time.

Some of the points to which I have called attention previously should be made more emphatic. The roentgenogram should be used as an accessory whenever possible, and the dried plate should be studied and its information added to the clinical findings and the surgeon's own experience in decision upon treatment. Complete circular encasements of plaster should be rarely used. Splints which are easily removed and arranged are much safer. Painful passive and active movements should be prohibited, but gentle massage and a shortened period of confinement in immobilizing dressings are in the trend of modern treatment. The value of the radical teaching of Lucas-Championnière's mobilization and of Bardenheuer's extension is doubtful. A median course must be adopted. What is really aimed at is a method of treatment which will ensure perfect anatomical restoration of form and function. Such a security of mechanical fixation is sought in those cases subjected to operation that after operation the bone may be stronger than before the fracture, and the fixation may last indefinitely. It must not depend on the frictional grip of nails or screws in the bone.[1]

The ideals of treatment may not be unattainable by those especially trained in this field of work. To further that possible attainment treatment of fractures in any large hospital should be assigned to the men who make special study of the pathology and end-results.

[1] Hey-Groves, Lancet, February 14 and 21, 1914; Warren, Lancet, July, 1909.

CHAPTER VI.

OPERATIVE TREATMENT OF OPEN AND CLOSED FRACTURES.

DIVERSE opinion exists in regard to the operative treatment of fractures open to the air. These fractures are open in two ways, first, by the violence of the trauma received causing laceration and crushing of the soft parts at or near the site of fracture, these injuries carrying deep into the wound any septic material on the skin, clothing or the body inflicting the damage; and second, by torsion and indirect violence, forcing sharp fragments within a limb to be protruded out through the tissues covering it. The first class contains all the potential infection one can imagine; the second class fares much better and gives a much higher percentage of non-infection, because the opening is generally small and has a valve-like action around the protruding fragment, which may stick out but a brief period and be reduced by muscular action of the patient at the first attempt to straighten the limb. Nevertheless this wound is exposed to the microörganisms on the skin and clothing which cover it, unless it happens that the individual falls or is thrown in a manner to drive the projecting point into the ground so that one cannot say that any one of these open fractures is clean, and the best practice is to consider them infected from the very start.

Treatment should be undertaken in three directions:

1. Treatment of the patient's general condition as caused by the injury.
2. Treatment of the infected wound.
3. Treatment of fracture.

First aid depends on the place of injury and the facilities at hand. If the patient is seen very shortly after the accident, and materials are at hand, the open wound should be drenched with half-strength tincture of iodine, after bleeding from large vessels is stopped by the application of hemostats or other means. The use of constrictors has been the cause of much damage in these cases. Untoward results, such as gangrene, or lowered resistance in a limb, that permits infection to get headway with possible loss of the member, or permanent paralyses from application over the path of nerve trunks may follow. Unskilled persons apply constrictors too tightly. If a limb is mangled and crushed beyond hope, the constrictor may save from fatal hemorrhage, but it should not be applied tighter than with force enough to stop sharp hemorrhage. Oozing is not harmful, but really beneficial from the standpoint of sepsis, and force should not be used that will

damage skin flaps for amputation stumps. Constrictors furnished in factory, mine, and railroad first-aid outfits are dangerous, and generally they are too narrow and are applied too tightly with many turns instead of one or two loops of sufficient pressure to stop free hemorrhage. When an open fracture is seen with one on the limb, it is the first duty of the surgeon to inquire as to its necessity.

With the bleeding reduced to a mere oozing, a sterile dressing is applied over the injured area. If sterile supplies are not at hand, frequently clean bed linen, handkerchiefs, or other material can be had. The limb is made as comfortable as possible by being bandaged to the body, a splint, or its fellow limb, and the patient hurried at once to quarters which will furnish opportunity for further care. The best place is the nearest hospital. No attempts at reduction, removal of foreign material, picking at the wound, sticking instruments or fingers into the wound, should be made in the first aid. This rule is without exception and if violated leads to much trouble. Should iodine not be at hand, the large, sterile dressing alone is sufficient. Stimulants, sedatives, or supportive treatment may be given if necessary, but no alcohol, and best merely warmth of extra coats or blankets and the most gentle handling in a recumbent position. Morphine hypodermically is good routine for avoidance of further shock and relief of pain.

Consideration is due first to the patient as an individual. His physical condition in general, age, reaction to the trauma and the extent of the injury and its complications must be understood. Treatment that can be given a robust working adult without danger of untoward result cannot be given to a child or senile adult or a person suffering from a constitutional disease. If severe shock is present, autotransfusion by bandaging the extremities from the distal end toward the trunk can be accomplished before removal to the place of permanent treatment. This throws a large share of the blood circulating in the extremities into the trunk and head, helps maintain blood-pressure, and wards off exhaustion of the vital centers in the medulla.

The matter of the value of trying to save a limb will be of immediate importance in many open fractures of long bones, and the general questions to be asked: Is tetanus or gas bacillus infection possibly present? Will the patient survive conservative treatment, involving months of confinement, infection, and the evils incident thereto? If the limb is saved, will it be useful functionally and cosmetically, or will it finally have to be discarded as in the way?

Primary amputations are dangerous if shock is present, and operation should be postponed twenty-four hours or more in cases of low blood-pressure, skin pallor, sweating and rapid, weak pulse, to obtain reaction. Amputation either immediate or at the time of recovery from shock is indicated:

(*a*) When the soft parts peripheral to the fracture are lacerated and crushed beyond hope of repair or regaining circulation.

(*b*) When there is circular destruction of all tissues at the site of fracture.

(*c*) When the skin has been stripped from three-quarters of the peripheral part with subadjacent muscular damage.

(*d*) When the important bloodvessels are known to be torn across and distal circulation is lost. Attempts at anastomosis or transplantation of bloodvessels always fail in the face of trauma of this character. Nerve injury is not so important.

(*e*) When the bone is thoroughly comminuted with accompanying tissue damage.

Estes of South Bethlehem, Pa., in an analysis of a series of cases, shows that 8.8 per cent. of open fractures treated conservatively died, while the average mortality after single major amputation is but 4.54 per cent. The average disability from open fractures of the femur or from both bones of the leg is thirteen months, while amputation gives a disability of not quite five months. He found[1] on analyzing 724 major amputations that more attention should be paid to the amount of skin injury than to the condition of the muscular and bone laceration, and that open fractures which sever a large nerve trunk do not require primary amputation nor do those with injury to one system of bloodvessels when there are two in the limb. Surgeons, after long experience with open fractures, are inclined to amputate to shorten disability and to allow return to occupation of some sort with an artificial limb. Months have been spent in conservative attempts to save legs which gave some function, to have the patient after a year or two seek amputation to obtain greater freedom furnished by an artificial limb. On the whole, attempts at conservation are primary; partial or complete amputation can be done later with little added risk.

Arrived at suitable quarters for permanent care, if conscious and suffering much pain, the patient should be given an anodyne. Clothing about the part involved or the whole body, if wet and dirty, should be removed and dry blankets applied. Shock is cared for by intravenous or subcutaneous injection of salt solution, from a pint to three pints, depending on the age and size of the individual. In this solution, in cases of severe depression, can be injected ten to fifteen minims of adrenalin chloride solution, 1 to 1000, mixed directly into the salt solution or injected slowly into the rubber tubing by means of an ordinary hypodermic syringe. The whole limb is now painted with iodine. Then parts of clothing, dirt, severed muscles, and crushed skin, are carefully and quickly picked out of the wound, under anesthesia if it can be safely given. If the fractured ends protrude, they are subjected to the same treatment as the rest of the wound.

In some institutions where large numbers of compound fractures are cared for, this technic is carried up to this point, and when

[1] Ann. of Surg., lviii, 39.

the iodine solution has dried, the parts, bone and all, are scrubbed with green soap and sterile water to remove the macroscopic dirt, cinders, grease or foreign material which is ground into the wound. At Gary, Ind., and at South Chicago Steel Mills, in hundreds of these cases treated, this technic has been adopted as giving the best results from the standpoint of time of disability, infections, primary healing, and lessened permanent damage. The author does not use the green-soap scrubbing in all cases. If a large amount of foreign material is in the wound it should be so treated. Bloodvessels, tendons, nerves, are cared for with a minimum amount of surgical attention; if tendons demand suture it should be done with catgut or kangaroo tendon. Bone ends are then reduced and placed in the best position obtainable, little or no suturing done in the muscle or fascial layers, and the wound left wide open, packed loosely with iodoform or plain gauze and a sufficient number of gutta-percha strips to ensure thorough drainage. A copious, dry, sterile dressing is applied, and some splint or fracture retention apparatus is loosely fixed outside to act as an immobilizer and protector. Much oozing of blood and serum will follow, demanding early and frequent change of dressings, so that the splint, if used at all, should be one that can be easily removed. At such dressings it is best to wear sterile rubber gloves and treat the case as though each handling were an operation itself, flooding the field with iodine to keep down bacterial activity. Antitetanic serum is given as routine.

No foreign material such as plates, screws, or nails is put in these wounds, as they are drained from the start, and it is merely a question of time before some bacteria, if only saprophytes, will work into the tissues. If the bone has been handled, the soft parts disturbed enough to permit the drilling of holes for wires or the screwing on of a plate, and then infection creeps in, osteomyelitis of greater extent can be expected than if these procedures were not attempted at this time. The foreign material acts also as an irritant and tends to prolong the case. If a fair reduction has been accomplished, the wound handled as indicated, and the drainage removed as soon as possible, it is surprising what a large percentage will give clean healing or show but slight seropurulent discharge from the superficial tissues. The oozing and drainage are really helpful in two ways: they carry out material and mechanically cleanse the region and fresh blood constantly running over and out of the tissues furnishes antibodies in the serum to overcome infection. It is not denied that a plate or wire or even an intramedullary bone transplant may be inserted and a happy result obtained in some cases, but in the light of the evidence of several years' treatment in an institution where all degrees of cases are entered, the outline as given seems to have the greatest value.

Men who use internal splints in fresh open fractures do not assert that they always get clean results, but they do assert that the fracture is properly reduced at once and even if infection follows and the plate is removed and the osteomyelitis is troublesome and demands further

operation, the final results are better. Immediate results are the relief of pain, and firm fixation which lessens shock and promotes early union. Fixation with Lambotte's rigid external plates is to be considered if foreign material is used.

One collection of 230 cases of open fracture has been reported by Pringle.[1] Males in these cases predominated over females at the rate of 9 to 1. The following resumé covers the injuries:

	Cases.	Immediate amputation.
Upper arm	39	20 = 51 per cent.
Forearm	30	9 = 29 "
Femur	21	4 = 19 "
Leg	139	33 = 23 "

Of the 230 cases, 10 died, 66, or 28.7 per cent., were amputated, and in 159 attempts were made to save the limb by the opening of the original wound in the skin and subcutaneous tissues, which were cut away where bruised or where dirt was ground into them. All pockets were spread open and made accessible to free drainage, gross dirt was picked out, the bone ends, if found to be dirty, were chiseled off, and all small bone fragments which had been detached from the periosteum, were removed. In some instances the bone ends were fixed by wire screws or plates and attempt was made to close all wounds without tension, lateral incisions being made to relax the tissues. Pringle believes that some fixation agent should be used in the bone even if the wound is left open. He keeps wet dressings on to avoid necrosis of the soft parts. One hundred and twelve cases were treated by internal fixation splints, and of these 9 died, from such causes as pneumonia, heart conditions, nephritis, brain injuries, and secondary amputation, which was performed in 7 cases. Forty-seven cases were treated by the cleaning process alone. Of these 4 died and in 7 there were secondary amputations. There were 6 instances of sepsis and 3 of necrosis of the skin. Pringle believes that stripping of the skin away from the limb by the accident is very important as to the prognosis. There were no deaths from tetanus in his cases, although the antitetanic serum was not used as a routine.

Another advocate of immediate fixation of open fractures,[2] prefers the gimlet and rod fixation, held in alignment by plaster of Paris or Freeman's external clamps, which are much like Lambotte's. He also believes that the intramedullary splint is contra-indicated and that complete drainage of the wound is necessary; so he packs it wide open with gauze after the application of the gimlets. Taylor[3] uses the same method and Parkhill[4] and Freeman[5] do not differ greatly. Levison,[6] who advocates immediate operation of selected closed fractures, takes the stand that open cases would be better handled

[1] Brit. Jour. of Surg., ii, No. 5, p. 102.
[2] Lillienthal, Ann. of Surg., lvi, 185; and lv, 883.
[3] New York Med. Jour., May 13, 1911.
[4] Ann. of Surg., xxvii.
[5] Ibid., 1904.
[6] California State Jour. Med., February, 1914.

without internal splint and must be allowed to heal completely. Bartlett,[1] in an article on operative treatment, states that although no operative procedure is wholly without risk, we should show definitely why we assume a moderate risk before submitting any bone case to operation. Yet under his indications for plates he states that "it is of course desirable in all fresh widely open fractures if shock be past." Fredet, of Paris, always allows open fractures to heal and cicatrize before attempting repair of deformity. Wire is of no value, as it does not hold firmly enough. In open fractures the capillary vessels in the traumatized bone and lacerated tissues are thrombosed or destroyed and for that reason alone, transplanted bloodvessels or bloodvessel suture will not be successful. The same result is manifested in intramedullary bone splinting with autogenous grafts in these fields. Deprived of the normal serum supply and exposed to infection, the grafts will fail to live, and, though they may act as mechanical supports, their placement within the medullary cavity is so deep and covered that on their death complications are bound to ensue. If rigid fixation is to be used, a silver plate with silver pegs instead of screws, which can be removed in a short time, seems to offer the rational treatment. Treatment is a matter for each surgeon to decide for himself, but the careful handling described, allowing the soft parts to heal, even if the bone position is bad, seems good surgery. If infection is present, it is easier to eradicate and becomes less extensive as a rule, if no bone plate or other foreign body is present. Its course is shorter, as ample drainage has been present from the first. As indicated, no operation in which a plate or internal splint is used should be drained, and if such splint is used in fresh open fractures, the tendency is to sew them up too closely, with the result that the gathering serum and exudate are dammed back, and if infected, spread much farther. When healing has resulted in simple treatment and the skin is in fit condition, the area can be entered under the rules to follow for operative treatment of closed fractures and an aseptic prompt healing be hoped for, after the deformity has been corrected at leisure and the proper internal splint, if one is needed, has been used.

THE RELATIVE VALUE OF NON-OPERATIVE AND OPERATIVE TREATMENT OF CLOSED FRACTURES.

The factors entering into this discussion are, briefly, age and occupation of patient, cosmetic and functional results of treatment; dangers of an anesthesia; time elapsing since accident and condition of skin and limb in general; the operator's surroundings and his skill.

1. **Age.**—Age must be considered. Children withstand operative interference and anesthesia less well than adults. Internal bone splints, excepting autogenous bone grafts, cause more irritation in children, either on account of the immature character of the bone or a lower

[1] Cleveland Med. Jour., xxii, No. 13.

infection resistance. Deformities and functional losses, which appear serious in adults, are not so important in the young, who have years to grow and many chances for natural overcoming of defects. On the other hand, elderly people, who never expect to do laboring work, or those to whom age is a factor from the standpoint of arterial and cardiac changes, or anesthetic danger or rest in bed, should receive most careful consideration before being subjected to operation.

2. **Occupation.**—Occupation is of importance in the making of a decision. If the patient's livelihood depends on the good use of an arm or leg, as in all laboring classes, an attempt to give the best function in the shortest time should be made.

3. **Cosmetic and Functional Results.**—Cosmetic and functional results, such as malunions, shortened legs, useless elbows or arms, angular deformities, are sources of embarrassment, and also through causing a restriction of activity in a person otherwise healthy, are worth considering when manipulative treatment without open operation has left the conditions. Open operation with anatomical reposition of fragments offers much to this class, not only in the way of improved appearance but also in the great increase of function which invariably follows when the axis of a long bone is put in proper alignment. In operating on forearm fractures where the displacement does not appear very bad, but where the function of the hand is far from good, one can demonstrate this effect almost as soon as the patient is out of the anesthesia, by getting freer and better movement in the fingers.

4. **Dangers of Anesthesia.**—Dangers of anesthesia and prolonged splinting or rest in bed must be weighed in connection with age and such constitutional disturbances as bronchitis, nephritis, diabetes, tuberculosis, chronic alcoholism, syphilis, and tabes or general paresis. Many of these conditions give contra-indication, and they should be included in a careful general examination of a patient about to be subjected to bone operation of any magnitude. Particularly is this so when foreign material is implanted.

5. **Time after Accident.**—Time after accident and condition of the skin and limb in general demand consideration. It appears best to delay from seven to twelve days after fracture before opening by operation. If pneumonia or delirium tremens or other untoward complications are to appear, they will usually show up within this period. Edema and swelling can be overcome by rest in a temporary dressing and the application of an ice-bag. The skin must receive careful attention. If abraded or scratched, or necrotic in small areas, it must be completely healed before the operation. Failure to observe this small point leads to many infections. Blebs and bullæ frequently appear on a leg or arm many days after injury. These should be aseptically evacuated at their lowest point and the whole area dried and made smooth before operation. Levison[1] makes a

[1] Loc. cit.

plea for immediate operation such as Lane advocates, to avoid the early shortening of muscles and callus formation, and it is his experience that with a perfect technic no chance for infection follows. Lambotte, Fredet and DuJarier all wait for ten to fifteen days.

6. **The Operator's Surroundings.**—The operator's surroundings and his skill are also important factors. Bone work should be done in properly appointed operative rooms where all instruments necessary are at hand and where the assistants and operating nurses understand the rigorousness of the technic and have been trained to obey it, because the operator must not have the worry of attending to them in addition to his own part of the work. Extension apparatus, suitable splints, plaster, large amounts of sterile supplies, and interested helpers are essential.

The operator should have every confidence in his own technic, which should be acquired by watching men who practice frequently, aided by his own critical improvements after work on the cadaver and lower animals under conditions similar to those of real operation. This work requires the utmost patience, physical endurance, and attention to details. Some operators are not fitted for it. The surgeon should never handle any suppurating wounds at times when doing this class of work unless he wears rubber gloves.

After Lane's exposition of operative treatment, other arguments, pro and con, have been advanced by able surgeons, based on their own and their colleagues' experiences with the use of the steel plate and other devices introduced subsequently. Scudder[1] considers it unfair to make comparison between the brilliant results of treatment by open operation and the rather poor results obtained by non-operative treatment, which is very frequently far from ideal in its application. The question arises whether we should not obtain better results from non-operative treatment if we put as much time and thought on it as we do on the other. The secret of the whole matter probably lies in the fact that surgeons and the profession as a whole have sadly neglected the treatment of fractures and until the advent of the roentgen ray both public and profession were satisfied with results. Since the enlightenment of this method of examination better treatment has been sought until, to quote Bloodgood[2] "more cases will come to operation when publicity has forced better methods of treatment upon the profession." The discussion of Scudder's statement, previously mentioned, brought out some firm opinions. Roberts, of Philadelphia, considered that too much operating had been done; he had two deaths in femur cases. G. G. Davis fittingly summed up the matter by saying that the man who gets too expert in an operation is dangerous. In another place Roberts[3] likens the surgical treatment of fractures to surgical treatment elsewhere; inasmuch as operators desire to handle fractures as they do aseptic laparotomies, they get irked at readjusting splints,

[1] Tr. Am. Surg. Assn., 1913. [2] Prog. Med., December, 1909.
[3] Arch. Int. de Chir., Gand, VI, p. 62.

casts and bandages and have consequently taken to the use of internal splints which are left alone and require no subsequent manipulations to maintain good position. Hitzrot in a study of end-results of fractures[1] says: "Much of the present disability occurring in uncomplicated fractures is due to neglect or lack of experience upon the part of the medical attendant. No method, however perfect, will succeed if improperly carried out in any of its details, and the too ready assumption of ability to treat any and all fractures on the part of the inexperienced lays the profession as a whole open to sharp criticism from Mr. Lane."

Ashhurst,[2] reporting 52 cases of forearm fractures treated without operation, believes that conservative treatment is as good or better, and that recovery takes place in a shorter time. Freeman[3] states that the tibia is one of the most frequent sites of delayed union especially when operated on, and that Koenig asserts this is on account of the blood-clots which have been removed, their stimulation to union being lost. Martin[4] considers that in operative treatment the time is not materially shortened and that union is usually delayed and the results are not uniformly good, but that they are infinitely better than could be secured by non-operative procedure.

The treatment of fracture is to restore function so that we must consider whether the interference with the soft parts in operation leads to additional disturbance. In the thigh we must not forget the importance of long-continued traction with a heavy weight, nor the position of abduction, nor elevation in children, and in women, especially on the forearm, of unsightly scars. Femur cases are those which come frequently to operation. Walker[5] reported 21 cases treated by Lane plates, Lambotte's and Lohman's clamps, and says that "sufficient evidence has been shown to definitely recommend operation for fracture of the femur in such cases as reduction is inadequate—this requires the ends to remain in apposition without obvious angulation or axial rotation and shortening should not be over one-half inch." Moore[6] believes that no operation should be done unless the patient's welfare demands it, considers the Lane plate the best fixation, and thinks that it is no detriment to the method to remove the plate when union is secured. It is also his opinion that the presence of a sinus is not a positive indication for removing the plate, as this sinus will often close with injections of bismuth paste or other applications. With this idea the author does not agree.

There is much discussion as to the influence of internal splints on bone union, whether they delay it, favor non-union, or are detrimental in any way. Personally I have had no cases of delayed union or non-union following the application of Lane plates. One case illustrated

[1] Ann. Surg., lv, 338.
[2] Am. Jour. Med. Sci., June, 1912, p. 843.
[3] Ann. Surg., September, 1911, p. 382.
[4] Jour. Am. Med. Assn., October 21, 1911.
[5] Tr. Am. Surg. Assn., 1912, xxx.
[6] Ann. Surg., lvi, 155.

in the chapter on Fracture of the Femur resulted in bending of the plate because the man left my service, and his cast was removed too soon, and he was allowed to bear weight. Although the bone shows deformity, the plate was firmly applied, no screw became loosened, and a good bony union resulted in spite of the fact that the man was an alcoholic. Two delayed unions which I have had followed the use of bone transplants in the tibia. The first was for a non-union of two years' duration in which an inlay graft was used. A nail was used to fasten the transplant. Several months after an apparently good result the wound broke down and a sinus appeared. I removed the nail and finding poor bony union in the tibia also removed my inlay transplant which was alive and bled when scraped. Later a Wassermann test proved positive, and after antispecific treatment firm union resulted. The second case was a fresh spiral fracture of the tibia, which was treated by an intramedullary bone peg. Union took over twelve weeks, with no infection and no abnormal symptoms. Roberts,[1] who likens open operation on bones to the former needless oöphorectomies and kidney fixations, reports a case of a male, aged twenty-nine years, whose leg was plated for a fracture of both bones two weeks after it was injured. In six weeks there was no union; the wound was clean and remained so. After sixteen weeks the plate was removed and he was given calcium salts, but there was no callus nor infection in the fracture. Thirty-three weeks after the fracture he began to have a little union. Darrach[2] says that it is his experience that firm union comes a little more slowly in operated fractures and that the smaller the foreign body the quicker the union. The results on the whole are much better, however, than could be obtained by other means. Plummer[3] says plating delays union, and Blake[4] says he saw cases of non-union in the femur supposedly due to wire, which, when plated afterward, resulted in prompt union. I believe that union is largely a matter of careful approximation, especially in the femur; that sometimes in the leg bones one cannot get union until very late with any means. Men of experience in this work have had just such cases. If the fixation is exact, we naturally expect union, as the bone ends and periosteum are in good position to regenerate bone, provided the patient has no idiosyncrasy in his osteogenetic tissue. An interesting case in this connection is reported by Magruder[5] from which he concludes that a closed fracture unites more quickly than one treated by the open method. His case was one of double comminuted fracture of both bones of the leg. One leg was opened and plated, the other not, and the unoperated side united four weeks sooner. He favors the use of a tinned-steel annealed wire rather than a plate, as there is less foreign material to traumatize

[1] Ann. Surg., lvii, 545.
[2] Jour. Am. Med. Assn., August 3, 1912.
[3] Jour. Iowa State Med., June, 1912.
[4] Surg., Gynec. and Obst., April, 1912, p. 338.
[5] Am. Jour. of Surg., xxviii, No. 1, p. 1.

the soft parts. Lane advises operation on all fractures, as does Koenig, while von Eiselsberg operates on the patella only.

Experimental study covering the type and results of different methods of internal bone splinting has been made by several observers. One of the most complete reports is by Hey-Groves, of Bristol,[1] who tried to decide whether rapidity and firmness of repair was better promoted by intramedullary pegs or by external plates and screws. He used mostly cats and operated on the fibula, because it is a separate bone and is supported by a strong tibia in these animals. His results showed that in fixation by plates and screws without additional external splint, the screw holes became enlarged, a process of absorption took place, and the plates became loose. Once they were loose, sepsis was very apt to be started. Long plates held by perforating pins, like cotter pins, which were bent back after passing through the whole shaft, gave good results with no sepsis and good use after two weeks. The union was complete and perfect with little external callus but much firm internal medullary callus. This was considered to be due to the pressure of the pins keeping the blood supply restricted in the periosteum so that he obtained an aseptic necrosis of the bone on the external surface up to the first pin on each side of the fracture. This does not coincide with observation on human bones by those men who assert that plating caused delayed union or non-union because the bone is deprived of its usual stimulus of friction and motion by the complete immobilization. Hey-Groves believes that the bone under these circumstances, instead of being alive with full vitality and reproductive activity, may be in an intermediate stage, circulation and tissue changes being at a low state but later becoming reactivated. Hence if the operative fixation is one which lasts but a short time, as plates and screws which become loose, the fracture will become displaced long before union occurs. If the fixation is more permanent, delay in vital action of the tissues does not matter, and the limb can be used for functional activities *while delayed repair goes on*. External splinting in addition seems absolutely necessary. The mere size of the plate has nothing to do with the possibility of irritation because a large plate firmly fixed will remain in place indefinitely, while a small plate gets loose and causes trouble. So he concludes that if a plate is attached in such a manner that there is some movement or mechanical irritation there follows bone absorption, fluid collection, sinus formation and finally sepsis. If the plate has been in place long enough to give firm union all is well; if not, it hinders repair and may bring on sepsis. Experiments were continued by using outside metal collars of aluminum plate or steel, magnesium, or bronze aluminum wire, which were put between bone and periosteum. Mechanically the collars gave good fixation. When they were removed, beneath the collar the bone was bare but not necrotic, the collar had interfered with the external callus, there was a vigorous internal

[1] Brit. Surg. Jour., vol. i, No. 3.

callus, but the method had no value practically. If the collar were put on loosely to favor external callus it would allow movement. His experiments with intramedullary bone pegs all resulted in breaking of the peg. He also used intramedullary pegs of decalcified bone with no success; similar pegs of gelatin and catgut were not strong enough, and pegs of horn and metallic magnesium were likewise of no value, as the magnesium absorbed too quickly. Intramedullary pegs of steel were tried with a small hole in the center, which was threaded with wire to allow it to be pulled down at equal length into each medullary cavity. In the femur, with this steel fixation, he obtained a tendency to excess callus, while in the tibia subnormal callus was the rule. Intramedullary splints of coiled wire were also tried, as they could be withdrawn, but they gave no good results. His best results came from transfixion of the ends of the bone with rigid extension of steel bars like Lambottes's or Hackenbrucks's external clamps, involving no attack at the seat of injury. In all trials good union with small callus resulted.

Fractures comminuted by crushing gave the following observations: (1) Fragments of periosteum left *in situ* gave good callus which was firm and solid, and functional result was excellent; (2) when fragments were removed, functional use was not so good as under (1), but the anatomical result was good. This I have verified in two cases done on man, one a femur, one a tibia; (3) exclusion of the periosteum gave good anatomical result, a good internal callus but no external callus, and the vigor of the changes of repair was impaired and a delay resulted.

The conclusion naturally follows that union will result even if the periosteum is removed, but union is a slower process without the vascular supply from the periosteum. As every fragment of bone is a center of regeneration in a comminuted fracture, all should be retained except in those instances near joints where mobility rather than strength is desired, in which cases it may be best to remove loose fragments or replace them perfectly for fear that callus may cause ankylosis. Any method, then, of internal splinting which affords a weak or loose union is a failure, because bone has not the properties of wood or metal and will not allow a screw thread to burrow into its substance. Furthermore, it does not sustain the thread long if its surface is subject to strain on account of poor mechanical fixation, but if this fixation is strong and lasts beyond the time that bony union takes place to make the support rigid, the threads of the screws will not cut their way out.

Corwin[1] concluded from his experiments that copper and brass plates or screws cause pathological irritations and changes. On the other hand, steel, iron or silver plates and screws are non-irritating. Plates put on denuded bone, or on the periosteum produce the same favorable result, while plates which are arched to cause little pressure on the bone or periosteum give no better results than those which

[1] Jour. Am. Med. Assn., lvii, 1351.

rest flat. The force necessary to remove both clean and infected screws from bone was tested experimentally by Bartlett and Hewitt.[1] They drove 34 screws, about one-half of which were infected, into dog long bones. At intervals of a few hours up to seventy-one days these were withdrawn in an attempt to ascertain the force required to dislodge them. This average force for No. 3, three-eighths inch clean screws in dog bones with a cortex of 2 mm. was $95\frac{4}{5}$ pounds. For infected screws the average was $41\frac{7}{9}$ pounds. For human bones, with a much thicker cortex, No. 5 or No. 7 screws can be used and eight or ten are put in at one time. Consequently a much greater force would be required to dislodge them if they are inserted in an aseptic manner into a drill hole the size of the screw barrel, and driven down to the head. In their experiments no infected screws dropped out of the bone, hence there must be external force and leverage which pulls them out when they are infected in human beings. For that reason a long immobilization is necessary for successful bone healing when foreign bodies are present.

In delayed union and non-union following open operation for plating it seems that we must acknowledge that the fixation by the plate was mechanically *inefficient;* there was no equilibrium of tension. Screws became loosened either because of too early use or lack of external support, and the bone ends slipped and did not unite. The ideal method of fixation is probably the indirect method, since by it the site of operation is not invaded, no material of any kind goes into the fracture but through small operative wounds which are made quickly, often with local anesthesia, rigid fixation and alignment are accomplished. As a result union is prompt and function very good, there is no sepsis nor fear of it, and the treatment is applicable to open and comminuted fractures.

Until hundreds or thousands of cases done by an approved technic can be carefully compared with a similar number of cases handled by the best non-operative methods, a final decision as to relative merits is impossible. Certain facts seem already established. Asepsis seems to be the keynote of successful work, and the operator should be in position to control his assistants or have merely one of whom he is sure. Open operation has demonstrated that external splints have not given perfect results on account of the pull of contracting muscles, which is really secondary to the all-important fact that the fragments were imperfectly reduced to proper position. As time elapses less foreign material is used, more simple reposition is practised by open method, with absorbable material to hold if needed. Delayed unions also, are caused not so much by the foreign material as by the long immobilization considered necessary to avoid bending of plates, buckling of nails or breaking of delicate intramedullary splints. This immobilization *per se* is not so bad, except that it deprives the limb of that functional use which stimulates health in it. It is not the irritation

[1] Jour. Am. Med. Assn., lvii, No. 17, p. 1347.

of movement that we have to thank in mobilized cases, as much as it is functional use and consequent normal healthful processes. Hence the value of early massage and light pressure and pulls in the *weight-bearing axis lines*. No lateral stresses should be allowed.

The reports of the committees of the English and American Surgical Societies touching on operative treatment of fractures are of much interest. The English recommendation is that the surgeon should be experienced and have suitable facilities for aseptic technic. No open treatment is undertaken where reduction can be made without incision. The best results are obtained by operating immediately after the accident, and open work is not needed in children, because deformities disappear. They also warn against operation in old ununited fractures as these are frequent failures. The American Committee divide surgeons into three groups:

1. Those who are inexperienced in the technic and requirements of open operation.
2. Surgeons of experience with poor or average hospital facilities.
3. Competent surgeons with excellent hospital and operating facilities and trained assistants.

Class 1 is barred completely. Class 2 should operate only in case of urgent necessity, and Class 3 alone should make free and frequent use of the open method.

Reviewing the operations for unopened fractures at the Cook County Hospital, Chicago, for seven years prior to 1914, one finds that there were 462 cases so treated. These were operated by different individuals and with various technic, very few with the asepsis indicated by Lane. It is interesting to note that there were 106 cases of patellar fracture operated out of a total number of 179 cases. All in the earlier years were wired, but gradually the kangaroo and catgut method of capsular and aponeurotic suture supplanted the wire, until at the end of the series very little wiring is recorded. Of these cases but 5 were infected. The same holds true of operated femur cases, of which there were 62, many of which became infected but resulted fairly except 2 cases which led to amputation and 1 to death on account of the infection. The fractures of both bones of the leg were difficult to maintain clean, 64 cases having been operated in this period. The humerus gave but 24 cases.

After the plate was introduced into use in America it is recorded as being used in 81 operations on closed fractures with variation in technic. Most of these were inserted on the tibia, the femur and the humerus, with a few scattering elsewhere. On the tibia were frequently placed two plates. Of these 81 cases plated in the hospital, 44 were known to have been infected, demanding the removal of the foreign body, while 14 were followed by non-union.

This gives a very high percentage of infection, but since the beginning of 1914 the number of infected cases has dropped, while the total of operative cases has increased. This is because of familiarity with the methods and better aseptic technic. Any figures gathered on the

work of men using decidedly different technic is quite worthless from the standpoint of the method's final value, but the statistics represent the results among a number of first class surgeons, and may be taken as an average result of a scattered group of the same number of operators. Individual results of men who pay strict attention to this work and its technic are much better.

A very instructive resumé of personal cases was made by Dr. George F. Thompson, of Chicago, at a meeting in Milwaukee, in December, 1913.[1] Fifty-eight cases of patellar fracture have been treated by him without a single infection, and in the four years previous to his statement he treated fractures by open operation and plating one hundred and six times, with resulting immediate and remote infections in twenty-four instances. He believes in and practises a rigid aseptic technic but acknowledges that operators frequently forget and violate the principles without appreciating the fact, and he cites instances where the foremost men have made these slips.

Open treatment for the correction of fracture displacements is so well established that a knowledge of its technic and the indications for its use should be as well known as the standard methods of non-operative treatment. While open operation on fracture not exposed to the air is new in the sense of our asepsis, operations of this character have without doubt been done for centuries, but it is idle to use space reviewing that phase of the subject, as the author's purpose is to give exposition of methods now in use or contemplated.

This branch of surgery is interesting, but demands painstaking care and hard labor, and the casual operator is apt to condemn open work if he does not do enough of it and has not acquired the technic by handling many cases. Part of his lesson is learned from each one. Statements expressed here are the result of the author's experience and observation of the work of many men and clinics, coupled with study of the best and most recent literature bearing on the subject. Lane's work has been the starting of this movement, and his well worked out ideas and beautiful technic will long remain a fundamental and be given due credit for opening this field. In past years operative work on closed fractures has been considered as in line with regular treatment in the case of certain bones. The patella has been looked upon as one of these, and the olecranon process of the ulna and others, ununited fractures, delayed unions, fibrous union and pseudarthroses have offered indication for operative interference. In most of this work little if any foreign material was used. Kangaroo tendon, ivory pegs and rarely nails of metal or silver-plated material were used but silver wire predominated. In certain classes, as those of the skull or spine, in operation for fracture or suspected fracture, foreign material was not used at all. These remarks apply rather to the long bones, the patella, and some of the flat bones as the scapula and mandible, and those cases which are primarily unopened to the air.

[1] Railway Surg. Jour., March, 1914.

OPERATIVE FRACTURES IN COOK COUNTY HOSPITAL. A CONSECUTIVE SERIES OF CASES DISCHARGED DURING 1914 AND THE EARLY PART OF 1915.

Bone involved.	Type of splint and operation.	Result as to sepsis.	Time in hospital before operation.	Result as to function.	Total time in hospital.
Nasal bone (crooked nose)	Bone transferred from tibia, ¼ x ¾	Good	2 days	Appears imperfect	5 weeks.
Astragalus and internal malleolus	Kangaroo tendon	Infected; second operation in fourteen weeks; took out necrotic piece of astragalus.	2 days	Able to bear some weight	6 months.
CLAVICLE:					
1—Outer and middle third	Plated	Clean	2 weeks	Starting	1 month.
2—Outer and middle third	Plated	Infected; refused to have it out	8 days	None	6 weeks.
3—Outer and middle third	Plated	Infection slight; plate removed	11 days	Fair	6 weeks.
4—Outer and middle third	Kangaroo	Clean	1 day	Good	6 weeks.
5—Sternal end	Sew periosteum	Clean	8 days	Still in cast	12 days.
6—Middle third, old fracture	Lane plate	Clean	1 week	Good	3 weeks.
SPINE:					
1—7 to 9 dorsal	Laminectomy	Died in 5 days	Same day	Death	5 days.
2—4 to 8 dorsal	Laminectomy	Died in 11 days	1 day	Death	11 days.
3—5 to 6 cervical	Laminectomy	Died in 1 day	3 days	Death	3 days.
4—1st lumbar and 12th dorsal	Laminectomy	Died in 3½ months	4 days	Death	3½ months.
PATELLA:					
1—Middle, ¾ inch separation	Wired and capsule sutured	Clean	Does not say	Does not say	9 weeks.
2—Middle, 2 inch separation	Catgut No. 3 around patella	Clean	4 days	....	2 weeks.
3—Middle	Catgut No. 5	Clean	1 day	Walks on crutches, posterior splint	16 days.
4—Middle	Silk around	Clean	11 days	In cast	6 weeks.
5—Middle	Mattress suture catgut	Clean	2 days	Knee stiff	6 weeks.
6—Middle	Kangaroo circling	Clean	6 days	....	25 days.
7—Middle	Kangaroo mattress	Clean	3 days	Not good, slight limp	2 months.
8—Comminuted	No. 5 heavy silk sutures	Infected	9 days	Death 18 days, bronchopneumonia	27 days.
9—Transverse	Mattress; silver wire	Clean	13 days	Knee stiff	2 months.
10—Transverse	Mattress; kangaroo tendon	Clean	9 days	Fair	5 weeks.
11—Upper quarter	Mattress; kangaroo tendon	Clean	3 days	Very good	6 weeks.
12—Transverse	Silver wire, purse-string and kangaroo	Clean	14 days	Knee a little stiff	7 weeks.
13—Both patellæ	Silk purse-string suture	Clean	4 days	Good	10 weeks.
SKULL:					
1—No subdural hemorrhage	Decompression	Clean	Same day	Good	9 days.
2—No subdural hemorrhage	Fragments elevated	Clean	Same day	Good	11 days.
3—No subdural hemorrhage	Decompression and fragments elevated	....	Same day	Death	2 days.
4—Basal	Decompression	Clean	2 days	Death	7 days.
5—Vault, no hemorrhage	Decompression	Clean	1 day	Complete recovery	13 days.
6—Basal	Decompression	....	1 day	Death	1 day.
7—Vault	Decompression	....	Same day	Death	Few hours.
8—Vault	Decompression and elevation	Clean	9 days	Complete recovery	1 month.
9—Vault	Decompression	....	Same day	Death	Few hours.
10—Vault	Decompression and elevation	....	Same day	Death	1 day.
11—Vault	Decompression	....	Same day	Death	2 days.
12—Vault	Decompression	....	Same day	Death	Few hours.
13—Vault	Decompression and elevation	Clean	2 days	Complete recovery	1 month.
14—Basal	Decompression	....	1 day	Death	2 days.

15—Basal and vault	Decompression	....	1 day	Death	14 days.
16—Old depressed	Bone plastic		4 months after decompression	Recovery; bone defect still present	1 month.
17—Vault depressed	Decompression	....	Same day	Recovery	1 month.
18—Basal	Decompression	....	1 day	Death	2 days.
19—Vault depressed and basal	Decompression	....	Same day	Recovery	1 month.
20—Vault, dura lacerated	Decompression	....	1 day	Death	2 weeks.
FOREARM BONES:					
1—Both bones; old malunion	Both bones; lane plate	Clean	2 days	Good	2 months.
2—Both bones; fibrous union	Both bones; lane plate	Clean	1 day	....	2 weeks.
3—Both bones	Bone peg in radius; kangaroo in ulna	Infected	12 days	Uncertain	6 weeks.
4—Both bones; five weeks' standing	Nailed	Clean	7 days	Poor	
5—Second operation five weeks later	Lane plate; ulna and radius	Clean	5 weeks	Not stated	2 months.
6—Both bones	Lane plate; ulna and radius	Infected	4 days	Still discharging	2½ months.
7—Ulna olecranon	Silver wire	Clean	15 days	40° painless motion	7 weeks.
8—Ulna olecranon	Ivory peg	Clean	5 days	Good	6 weeks.
9—Ulna olecranon; old fibrous union; ulnar nerve caught	Bone peg	Infected	......	Poor	6 months.
10—Ulna olecranon comminuted	Screw	Clean	2 days	Excellent	2½ weeks.
11—Both bones malunion	Wired	Cleaned	4 days	Good	7 weeks.
12—Olecranon ulna comminuted	Catgut	Infected	15 days	Fair	4 weeks.
13—Radius, middle, malunion after Lane plate	Plate removed	Clean	10 days	Good	2 months.
14—Radius, lower third	Bone peg	Clean	17 days	Fair	9 weeks.
HUMERUS:					
1—Surgical neck	Lane plate	Clean	8 days	Fair	4 months.
2—Shaft plus suture nerve	None (remove callus)	Clean	Old compound fracture 5 months before plated and infected	Good	2 months.
3—Shaft non-union	Plated	Clean	2 days	Poor; no union	7 weeks.
4—External condyle	Removal	Clean	1 day old fracture	Good	20 days.
5—Infracondylar transverse	Plate	Clean	3 days	Good	6 weeks.
6—Shaft; lower third oblique	Plate resect both ends	Clean	2 days	Fair	11 weeks.
7—Surgical neck	Plate	Clean	24 days	Not stated	6 weeks.
8—Neck	Nailed (3)	Clean	6 days	Fair	10 weeks.
9—Shaft	Intramedullary	Clean	2 days	Excellent	5 weeks.
10—Tuberosity	Ivory peg	Clean	3 days	(Pulled out, repaired later, poor improvement)	3½ months.
11—Surgical neck and head	Kangaroo tendon	Clean	10 days	Poor	6 weeks.
12—Surgical neck	Plated	Clean	6 days	Good	5 weeks.
13—Shaft of middle and lower third	Intramedullary	Infected	5 days	Poor; large callus and nerve caught	2 months.
14—Surgical neck	Intramedullary	Clean	2 days	Good	6 weeks.
15—Shaft, upper and middle third, spiral	Intramedullary	Clean	3 days	Good	7 weeks.
16—Supracondylar into joint	Silver wire and ivory peg	Clean	15 days	Fair	17 days.
17—Non-union of middle third	Bone peg intramedullary	Clean	15 days	Excellent	2 months.
18—Internal condyle	Nailed	Clean	3 days	Motion of extension limited	3 months.
19—Comminuted of neck	Intramedullary bone peg	Infected	19 days	Limited motion; bony union	5 weeks.
20—Surgical neck	Intramedullary bone peg	Clean	14 days	Good	6 weeks.
21—Condylar fracture into joint	Replacement	Clean	19 days	Fair, flexion complete	7 weeks.
22—Oblique middle third	Silver wires	Clean	12 days	Good	1 month.

OPERATIVE FRACTURES IN COOK COUNTY HOSPITAL. A CONSECUTIVE SERIES OF CASES DISCHARGED DURING 1914 AND THE EARLY PART OF 1915.

Bone involved.	Type of splint and operation.	Result as to sepsis.	Time in hospital before operation.	Result as to function.	Total time in hospital.
FEMUR:					
1—Upper and middle third	Lane plate	Clean on leaving nine days	Not stated	Out too early	9 days.
2—Middle, 9-year-old child	Lane plate	Infected	17 days (8 weeks old fracture)	Plate out; two other operations	5½ months.
3—Upper and middle third transverse; 10-year-old child	Lane plate	Clean	17 days	Clean to discharge	10 weeks.
4—Base of neck, 65 years old	Screw through trochanter	Some infection	Not stated	Too soon	1 month.
5—Upper third, 11 years old	Plated	Some infection	5 days	Recovery	10 weeks.
6—Upper third, 20 years old	Plated	Clean	3 weeks	Good	3½ months.
7—Upper third, 35 years old	Plated	Clean	1 week	Good; later buckled plate by walking too soon	17 days.
8—Neck impacted, 1 inch shortening, 24-year-old	20-penny and screws	Clean	Same day	Very good	6 weeks.
9—Neck in 22-year-old	Nailed	Clean	2 days	Good	6 weeks.
10—Neck in 60-year-old	Screws	Clean	5 weeks	Good	3 months.
11—Middle shaft, 18-year-old	Plated	Clean	16 days	Good	2 months.
12—Upper and middle third transverse in 23-year-old	Intramedullary	Clean	6 days	Good; large callus	3 months.
13—Shaft of upper third oblique; 55-year-old	Intramedullary	Clean	1 month	Death; shock, same day	
14—Neck, female, 65-year-old	Nailed	Clean	14 months ago	Nails hurt; took out	1 month.
15—Shaft, child, 7-year-old	Plated	Clean	1 month	Good	3 months.
16—Middle shaft, transverse	Intramedullary	Clean	5 days	Good	7 months.
17—Middle third oblique, male, 19 years	Plated	Clean	10 days	Good	2 months.
18—Upper third	Intramedullary from own splinter	Clean	3 days	Very good	5½ months.
19—Neck, male, 49 years	Intramedullary	Clean	1 month	Fair	7 months.
20—Neck, male, 47 years	Intramedullary	Clean	5 days	Incomplete recovery	6 months.
21—Shaft, male, 29 years	Amputation	Clean	4 days	Death	
22—Lower third spiral, male, 36 years	Plate, screws, and wire	Clean	6 days	Good	5 months.
23—Neck, old nail fracture; nails slipped out	Intramedullary	Clean	7 days	Fair	5 months.
24—Middle and upper third oblique; 8-year-old	Plated	Clean	24 days	Recovery	3 months.
25—Upper third spiral, male, 59 years	Two plates	Clean	10 days	Perfect (Smith)	4½ months.
26—Shaft, male, 20 years	Plate	Clean	5 weeks	Good; excessive callus	3 months.
27—Comminuted junction of middle and upper third; lesser trochanter	Kangaroo tendon	Clean	17 days	Fair	9 weeks.
28—Neck	Two screws	Clean	6 days	Good (?)	2 months.
29—Internal condyle	Replacement	Clean	5 days	Motion limited	4 months.
30—Oblique middle third, malunion	Lane plate	Clean	2 months	Crutches	3½ months.
31—Lower third malunion	Lane plate	....	7 weeks	Death in two days	
32—Neck	Bone peg	Infected	12 days	Death	5 weeks.
33—Shaft, malunion	Replacement	Clean	10 weeks	1 inch short	5½ months.
34—Greater trochanter	Ivory and steel nail	Clean	20 days	Good	10 weeks.
35—Upper third, spiral	Intramedullary bone peg	Infected	......	Death	23 days.

LEG BONES:					
1—Both bones of spiral 4 inches from ankle	Plated	Infected; plate out in 7 weeks	16 days	Still discharging, open on leaving	11 weeks.
2—Both bones of upper and middle third spiral	Intramedullary	Clean	Not stated	Good	7 weeks.
3—Both bones of shaft, 2½ months; male, 30 years	Plated	Clean	11 days	Good	4 months.
4—Both bones of shaft; fibrous union	Plated	Clean	5 days	Good	2 months.
5—Both bones of shaft; child	Plated	Clean (?)	2 days	Good; plate taken out after 3 months	3 months.
6—Supramalleolar, male, 60 years	Plated	Clean	3 weeks	Death, pneumonia	1 month.
7—Bimalleolar	Nailed	Clean	5 days	Very good	7 weeks.
8—Both bones, spiral, junction of middle and lower third	Plated	Clean	3 weeks	Good	2 months.
9—Bimalleolar	Nailed	Clean	2 days	Good	2 months.
10—Both bones of middle and lower third; wedge piece	Plated	Infected; plate removed five weeks	20 days	Good	2 months.
11—Tibia ununited of middle and lower third	Curetted	Clean	3 days	Good	2 months.
12—Tibia ununited; lower third	Plated	Infected; plate out	12 days	Improved; second operation	4½ months.
13—Both bones; non-union fascia between	Intramedullary	Clean	9 weeks	Good	5 months.
14—Both bones of middle and lower third	Ends squared; intramedullary	Clean	2 months	Improved	10 weeks.
15—Both bones; fascia between	Plated	Clean; plate in seven weeks	14 days	Poor	3 months.
16—Both bones; upper third of, oblique and spiral	Intramedullary	Clean	6 days	Good	2 months.
17—Both bones; tibia of lower third; fibula, upper third	Intramedullary; tibia kangaroo	Clean	14 days	Good	2 months.
18—Tibia, comminuted	Sutured, kangaroo, and encircle	Clean	8 days	Good	4½ months.
19—Tibia, spiral	Plated	Infected; plate out in two months	14 days	Poor; 3 operations and still discharging	8 months.
20—Bimalleolar	Nailed	Clean	4 days	Good	3 months.
21—Both bones of tibia, lower third; fibula, upper third; spiral	Intramedullary after fracture of fibula on same level	Clean	14 days	Fair	3 months.
22—Both bones of lower third; spiral	Plated	Clean	7 days	Good	6 weeks.
23—Both bones of lower third; junction	Plated	Clean	14 days	Good	7 weeks.
24—Tibia, 2 inches above ankle	Plated	Clean	7 days	Good	3½ months.
25—Bimalleolar	Nailed	Clean	4 days	Good	3½ months.
26—Tibia, lower third; fibula, upper third	Intramedullary fibula refractured	Clean	14 days	Good; limps slightly	2½ months.
27—Spiral, 2½ inches above ankle	Two screws	Clean	9 days	Good	6 weeks.
28—Fibrous union, spiral fracture of lower third	Inlay bone transplanted	Clean	13 days	Not stated	5 months.
29—Fibula, 3 inches above ankle	Screwed	Clean	9 days	Good	3 weeks.
30—Spiral, lower third	Beef bone intramedullary dowel	Clean	10 days	Good	2 months.
31—Spiral, both bones; lower third	Steinmann's nail extension	Clean	2 days	Good	10 weeks.
32—Transverse, both bones; middle third	Intramedullary bone peg	Clean	7 days	Good	5 months.
33—Both bones, lower third	Intramedullary bone peg	Clean	6 days	Excellent	2 months.
34—Bimalleolar	Nailed	Clean	3 days	Good	2 months.
35—Both bones; comminuted lower end	Screwed	Clean	9 days	Good	2½ months.
36—Bimalleolar	Nailed	Clean	6 days	Good	6 weeks.
37—Spiral tibia; middle third	Intramedullary bone peg	Clean	9 days	Excellent	9 weeks.
38—Oblique; both bones	Intramedullary bone peg	Clean	23 days	Not stated	1 month.

The accompanying table is a resumé of closed fractures operated upon and discharged from the Cook County Hospital during the year 1914 and part of 1915. The cases operated on during the seven years prior to 1914 with some classification as to the bone involved and the character of the internal splint used have been already given. These cases made a total number of 462. During the year 1914 and part of 1915 there were discharged from the hospital 155 cases of this character, making a total list of operated closed fracture of 617 cases. For 1914 and part of 1915 I have made a careful statistical review, which is interesting inasmuch as it shows increase in the number of cases, better results from the standpoint of asepsis and function obtained, and valuable detailed information as to the character of the operation. In this enumeration are included the skull and spine fractures which were operated upon for decompression purposes or the elevation of fragments, although no internal splints were used. Twenty-one different operators performed these, many of them using a rigid aseptic technic of a greater or less degree. One operation was performed by Sir William Lane.

Reference to the table reveals the fact that out of 42 operations in which the Lane plate was used 8 were infected, giving a proportion of about 20 per cent., less than half the percentage of infections prior to that year. There was one death from pneumonia a week after operation and one two days after operation. Taking all the cases in which the plate was used during eight years, we find that 123 occurred, with 52 known infections or 42 per cent. plus. Two plates were removed which gave promise of later becoming infected. In 1914 the average length of hospital stay of *all* plated cases was seven and three-quarters weeks, while the average stay of the plated cases which were infected was fourteen and one-half weeks, and of the 8 infected cases 6 still had small sinuses discharging pus when they left, and 3 had been subjected to one or more operations for osteomyelitis following the infection.

Thirty-four cases treated by intramedullary splints of autogenous bone yielded 5 infections, 2 of which cleared up in a short time without subsequent operation. One (a humerus) had an excessive amount of callus in which the radial nerve became involved, and although seen many months afterward had no discharge from the arm and refused to have the nerve freed and packed about with fat. There was one death on the day of operation from shock and two deaths at later periods as long as twenty-three days after operation. The average hospital stay of patients treated by intramedullary splints was fifteen and one-quarter weeks, possibly prolonged because we were anxious to observe them until entirely well and to determine if possible the rate of absorption of the piece of bone within the canal. Two had large callus, which slowly absorbed later and after a few months was not noticeable.

The operations in which nails and screws or both were used, 21 in number, yielded but one slight infection and had an average hospital stay of eight and one-quarter weeks. The operations in which kan-

garoo tendon or catgut was used yielded one infection also and had an average hospital stay of eight and two-thirds weeks. All the patients treated by laminectomy for fracture of the spine died except one, and of the 20 skull decompressions 12 ended fatally. Six fractures of long bones were treated solely by wiring, three by ivory nails or pegs and one each by silk suture and periosteal suture. The 6 cases of simple reposition without internal splint all terminated happily.

SELECTION OF CASES—INDICATIONS FOR INTERNAL BONE SPLINTING.

Not all fractures are considered objects for open reposition, plating or other internal splints. Under the heading of each bone discussed is given such types as experience has shown can be successfully subjected to operation. The foregoing points must be carefully weighed, especial attention given to the occupation, disability, permanent deformity, danger of sepsis and anesthesia. Fractures of the patella, olecranon, femur, greater tuberosity of the humerus and a few others seem to demand primary operation, under the restrictions mentioned. All fractures should be subjected to attempts at reduction and careful splinting, with the aid of anesthesia, if needed, before operation is undertaken. The results should be checked by skiagram. Marked shortening, irreducible deformities of rotation and overriding, deformities which will interfere seriously with function and wage earning, are indications for open replacement. Thoroughly impacted fractures near the joint offer strong indication for operation and should be considered minutely on consultation and with good skiagrams. They can frequently be benefited exceedingly. In brief, Walton's operative indications are to be remembered. They are: (*a*) implication of joints; (*b*) neighboring dislocation; (*c*) failure to obtain a good position; (*d*) malunion; (*e*) involvement of vessels and nerves; (*f*) non-union; (*g*) separation of small fragments.

Preparation for Operation.—1. **The Patient.**—The usual preparation for anesthesia in accordance with surgical principles is made. As a rule these operations are long, especially if plaster has to be applied after the operative work and the patient kept asleep until this is set. Close attention to the skin condition as mentioned should be given by the operator himself. Small abrasions or ulcerated areas remote from the field should be covered with collodion seals. No patient recovering from an acute infectious disease, or possessing a known infection of any kind in the body, should undergo bone operation for fracture. Careful general examination should exclude any condition unfavorable to prompt healing of both bone and soft parts, and the patient should have explained to him the character of the operation, and the dangers of infection, should it occur, provided he has sufficient intelligence to grasp the information.

If extension by adhesive plaster has been used in attempts to reduce the deformity, it must be removed and the whole limb shaved. Dry

shaving is the best, and the skin must not be nicked into by the blade. After the shaving the part can be washed in alcohol (95 per cent.) and then enveloped with a dry sterile dressing on the night before operation, or no dressing of any kind need be applied, that the skin may not become macerated but be in a natural condition. Clean bedding and night clothes should be supplied.

When the patient is anesthetized, the part to be worked on is completely painted with tincture of iodine U. S. P. There should be no preliminary washing with water or bichloride of mercury solution. If the operation is upon an arm the surface from finger tips well up on to the chest is painted with shaving of the axillary hair if the humerus is to be opened; if upon a leg, the whole from and including the foot up on to the pelvis is painted, and the part remote from the field is covered with a sterile legging or towel, to be excluded. If extension is to be applied other than by manual force of the operator and his immediate assistants, this should be carefully arranged for before the limb is prepared, and the patient should be placed on the pelvic rest with suitable support beneath the back and head, and the extension from the ankle fastened. The patient once asleep and in good position, the skin preparation is performed and a clean sheet applied. If the skin is very heavy, a second coating of iodine can now be spread over the immediate operative field and allowed to dry slowly, following which nothing but instruments are to touch the skin, not even a gloved finger.

2. **Preparation of the Operating Room.**—It should be warm and the windows closed, that a dust and microbe-bearing draft of air may not blow on the instrument table or the operative field. A proper supply of sand bags should be at hand, reserve sheets and gloves for the operators, and a sufficient number of non-operating assistants, who may be called upon to manipulate a limb in different directions, so that the operating help will not be led to endanger their own asepsis in doing this work and may be kept right in the operating field to prevent its derangement. When intramedullary splinting with bone from the tibia is to be performed, the area on the opposite leg from the side to be operated on is chosen, is prepared as for the major part of the work and is covered with sterile towels until time for opening. A good position for the large instrument table, bearing the heavy instruments, is directly behind the operator, the operative nurse working alongside it.

3. **Preparation of Operative Nurse and Instruments.**—The nurse scrubs in the usual manner and puts on gloves as soon as possible, taking care, as do all concerned in the operation, to put the gloves on without touching the finger portion with the bare hand. One sees operators with splendid operative technic putting on one sterile glove and then pushing on the fingers of this glove with the other bare hand, transferring to the glove in the rubbing process whatever infectious agents have not been removed from the hand in scrubbing. The instruments necessary depend on the operator. Large bone-holding

forceps are useful in all cases. Good drills are needed with a sufficient supply to provide for breakage or contamination during operation. Drills should be of such size that they will correspond to the screws, nails, or wires used. Chisels should be sharp, carpenter's chisels in sets of eight from one-quarter to two inches in width should be on hand, as well as heavy, long-handled periosteotomes, small and large saws, and an abundance of hemostats.

Boiled instruments are laid out by the operative nurse, who uses large forceps with which to handle them, never touching any instrument with her hands. Needles are threaded with catgut by forceps, not by hands. The instruments used by the nurse are laid to one side, and that portion of them which comes in contact with the material to go into the wound must not touch hands. All instruments and sponges, plates, screws, etc., are handled by forceps and given directly to the operator or placed on the small instrument table near the field. The operator and assistants prepare with the same precaution regarding assumption of gloves.

4. **Operative Technic.**—*The Incision.*—If bone plating is undertaken, the incision is made in the long axis of the limb on the side where approach to the fracture is easiest and involves the injury of no important structure. Long incisions are needed for plating. These should be made boldly in the first attempt, the knife cutting down through the skin alone, and then being laid aside. This is done because it is impossible to sterilize the skin through all its layers, and bacteria are present in the hair and sweat follicles which will adhere to the blade. The skin opened, sheets of sterile gauze or light towels are placed along the incised edge of hemostats or special sharp-pointed clamps, to exclude the edge and all surrounding area from the open wound. With a fresh knife the incision is deepened, and fascia and muscles divided down to the bone. If small tendons or nerves appear in the field, they are avoided and retracted. The operator does not put his fingers into the wound; the assistants in sponging do not pick up sponges with their hands but use a forceps and after wiping out the field once, discard the sponge, picking up a fresh one. Retractors have long handles, and the end which goes into the wound never comes in contact with gloved hands. The closest attention is necessary to train one's self and assistants to maintenance of this technic.

In approaching the point of fracture, one is guided by finding darkened extravasated blood thrown out in the immediate neighborhood of the break. The bone ends once found, the area is palpated by a blunt nosed hemostat, and if necessary the muscles and fascia are reflected from the fragments and these are then caught in the grasp of bone-holding forceps. By means of local manipulation and extension or change of position by the assistant, reduction can be accomplished. Even when the ends are serrated, by patient efforts the fragments can be brought into perfect anatomical position. In oblique fractures with overriding, the extension, which is furnished so completely by the fracture table, must be held while the plate is applied, the fragment

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being steadied in the clasp of a large bone-holding forceps which permits the plate to slip between its jaws and be applied. Some operators do not appreciate the value of strong extension by mechanical means, and many devices have been brought out to force the bone ends into apposition. Bartlett[1] suggested for lining up long bones a clamp which was composed of two parts, a male blade and a female blade with two prongs, the latter portion slipping down over the male blade and holding the bone in position by a thumb-screw. This is very useful after the bones are in extension. Colt[2] believes that the turnbuckle brought out by Gerster is not needed if a Thomas splint is applied previous to operation and the elongation is kept up by an extension. Later Coerr[3] introduced a double lever for reduction of overriding before the Lowman clamp is applied to hold the fragments during plating. The fracture table or suitable mechanical extension apparatus renders these devices superfluous.

If a Lane plate or a bone plate with bone screws is used, the technic of application is the same. The plate is held in the forceps and applied along the shaft of the bone. When its proper position is established, the first screw hole is driven well into the shaft with a drill, generally opening into the medulla. The screw is then applied by a screw-holding driver and is forced part way home before the grasping apparatus which holds the screw is loosened. It is then tightened and the remaining screws put in as quickly as possible. If bone or ivory screws are used in a plate of like character, they can be driven in as far as advisable and the remaining projecting portion cut off with cutting forceps.

Experience and practice will teach the operator just how deep a screw hole must be for the size of screws used and the bone he is working on. If a screw is partly driven and sticks, it is as well to leave it alone if it holds securely as to attempt to withdraw it and redrill the hole. The work should be done quickly and methodically. Screws should be set in at right angles to the long axis of the bone and tightened snugly in a workman-like manner. Slovenly or unmechanical work has no place in this field, and the postoperative skiagram, which shows clearly the position of the plate and screws, is a good criterion of the operator's technic. In oblique fractures of the femur and sometimes of the tibia, it may be necessary to insert two plates, one generally smaller than the other, acting merely as a stay across the fracture line at a distance around the shaft from the main support.

Only large bloodvessels are ligated if bleeding. Oozing, which may be annoying at first, soon stops, and it is best to work without a constrictor for reasons already mentioned. If a vessel is ligated the knots must be tied with forceps; there must be no admission of the fingers into the wound nor handling of the catgut. In plating the femur with a ten- or twelve-inch incision, one rarely has to tie any deep points. Plates applied over the periosteum are less liable to cause

[1] Ann. of Surg., lv, 998. [2] Ibid., lviii, 490.
[3] Surg., Gynec. and Obst., xviii, No. 4, 521.

irritation and to interfere with union, nor do they later tend to be overgrown with bone. Closure of the incision is made by a continuous stitch of catgut, through the muscles and deep fascia. This must be applied by forceps, and the knots tied by forceps, and all tissues must be brought snugly together. The skin protection of gauze or towels is then removed and the skin closed, either by Michel clips with exact approximation of the edges, or by interrupted silkworm gut with a finer horsehair suture in the incision line. The incision is then painted with iodine and a copious dressing to catch oozing blood is put on and bound with sterile roller bandages. Outside of this, the part being carefully held in its corrected position, the plaster or other splint is applied before the patient awakens and the position maintained until all is hardened and immobilization is satisfactory. No drainage is used. All structures are closed tightly, and yet there is oozing into the dressings. Drainage invites infection to travel down into the wound and is not necessary.

If in certain areas other operative steps are demanded, they are indicated under the heading of each bone dealt with.

Postoperative Care.—Casts, splints, and dressings must be inspected frequently in the first twenty-four hours. When awakening, the patient must be restrained from violent motions which might displace the internal adjustment and when awake must be cautioned not to move the affected part. Should signs of local compression or interference with circulation appear, the cast should be cut away at once and loosened freely. If the oozing penetrates the cast, the dressings can be changed down to the skin through a window cut over the wound. Fresh dry dressing always stops the oozing. Casts saturated with blood begin to have a bad odor in a few days when the saprophytes cause fermentation. They must then be changed entirely and a new cast applied. Care in handling the limb must be exercised. If body casts or those involving the thigh or sacral region are applied they must be preserved against contamination with urine or fecal material. This is avoided by cutting them well away around the pubes and buttocks and using the bed-pan cautiously. By strapping the plaster edges with adhesive or painting them with shellac one may obtain further protection.

Bed-sores, decubitus ulcers, may also occur. After body casts are applied the patient should lie on pillows placed squarely across beneath him, and the areas over the sacrum and buttocks should be inspected daily for beginning redness, which is sufficient indication to cut away the plaster and readjust the padding.

After the application of internal bone splints it is very necessary that the external splinting should be of adequate strength, should immobilize, and should be left on for the proper period of confinement. One must consider that the bone fragments within have been delicately and positively adjusted, sometimes under severe strain of mechanical extension, and the external splinting must take up this strain and hold the position obtained without chance of yielding. In some ways

the idea seems to prevail that internal splints, particularly Lane plates, are adequate of themselves to hold fractures without external help. This is a great error, accounting for many poor results, and should be corrected. The splint should be left on as long as if no internal splints are used at all, and the immobilization should be as complete as can be obtained (Fig. 34).

The technic of removal of internal splints is simple. If pain, redness or tenderness about the site of insertion, or a sinus discharging pus develops at any time, the advisability of their removal becomes immediate. If the bone has healed in the position wished for and the signs of irritation develop late, the splint, if non-absorbable, should be cut down upon and removed. As a rule in plates, wires, and nails more infection will be found down in the bone than was anticipated. Around the edges of the plate there is frequently marked proliferation of bone quite completely embedding it, and yet granulation tissue will be found beneath when the proliferated bone is chiseled away.

FIG. 34.—Removed bone plate after infection. The attached bone and screws all lifted out in one piece.

If non-union has occurred or the original plating was poorly done from a mechanical standpoint, or the patient was allowed to use the leg or arm before firm bony union had followed, screws will be found loose even in the absence of infection, absorption having taken place around the track of their insertion. Martin[1] recognizes this fact and suggests that external support during the time needed for union should be firm to prevent twisting and angling strains at the fracture site. The same statement holds as to metal nails. The plate is removed and the granulation scraped away. The screw holes into the medulla are left alone unless there is evidence of virulent infection deep into the bone, in which event the medullary cavity should be chiseled open to remove necrotic bone and allow for drainage. The skin wound should be but partly closed after all is swabbed out with iodine, and a gutta-percha drain should be placed, extending out of the most dependent portion of the wound. This drains freely for some time, slowly fills

[1] Jour. Am. Med. Assn., lvii, No. 17, p. 1353.

in from the bottom and in attenuated or weak infections is soon completely healed with no trouble. If sufficient drainage is not instituted or the wound is too thoroughly closed, pockets of pus form and burrow under pressure through the muscle and fascial planes.

The technic of intramedullary splinting by autogenous bone grafts differs from that of Lane plates or silver wire or other internal appliances. The fractured ends being exposed by the same method as in plating, they are brought out through the incision by being grasped at each end with a bone forceps. If the fracture is one which has healed in malposition, or one in which there has been callus thrown out, it is often necessary to cut through the site of fracture with a chisel, making this cut at right angles to the axis of the bone. If the bone attacked is one of two, as in the forearm or leg, the companion bone, if not already fractured and loose must be broken through likewise by chiseling, sometimes through a separate incision. In some instances cutting through the interosseous ligament will allow enough freedom of the fractured bone to permit insertion of the bone peg.

The bone ends being turned out, if the fracture is fresh the medullary cavity is apparent, and the blood-clot in it is scraped out with a curette or reamed out with a reamer. If the callus has formed and has plugged the medullary opening, it must be gently cut away by a sharp chisel and the medulla opened in each fragment by drilling and curetting. The shaft of the tibia on the opposite side is next opened by an incision directly over its anterior edge. This incision may be straight or curved outward as desired. The fascia and sheath of the tibialis anticus muscle are opened and the tissues reflected back on both sides, the skin being held out of the way by a broad, flat retractor. Measurement of the fracture will determine how large a piece of bone is needed. This is marked off on the tibial edge, each end indicated by a cross cut through the periosteum and bone with a metacarpal or rotary saw and the anterior edge of the bone sawed or chiseled off, with a broad-bladed carpenter's chisel. Practice with a chisel will lead to satisfactory removal of the splint if the electric saw cannot be obtained. An expensive mechanical saw is a nuisance if it is continually getting out of order, and it possibly opens a chance for infection in needing water to be dripped on the blade as it works, to avoid burning (Fig. 35).

When the fragment of required size is loosened it is held in a bone holding forceps, not allowed to touch anything and while the assistant sews the muscle and fascia over the denuded tibial surface the operator returns to his fractured site and fits the splint into the medulla of one fragment, making sure first that it is not too long nor wide to fit into the opposite side, always holding the splint in forceps. If satisfactory, the splint is gently tapped into the medullary cavity and then by the manipulating of the limb to such an angle that the other end can be slipped into the medullary cavity of the opposite fragment, the shaft is brought into alignment. This reduction completely covers the intramedullary splint.

Rotatory displacement is corrected and the bone will be found to fit perfectly. Closure is the same as after plating. This operation can frequently be done quicker and through a smaller incision than plating.

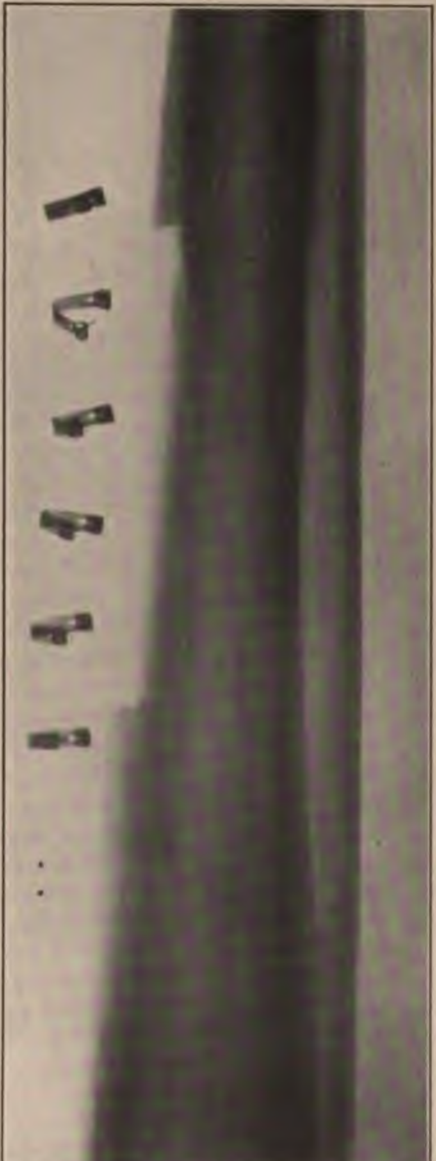


FIG. 35.—The bone field shows edge of tibia from which graft is taken, used in repair by intramedullary grafting. Clips show skin edge. In four weeks these shins often feel normal but skiagram does not show the bone filled in so early.

The site of the tibia from which the transplant is taken rarely gives any trouble. It should never become infected and usually after four to six weeks fills in clinically, so that the finger running down the shaft of the bone fails to find a distinct hiatus where the bone was removed. In some cases this filling in is greatly delayed—after four months I have found the depression still unfilled owing to complete removal of periosteum. It has been suggested by Truslow[1] that this defect be filled in with bone wax. Rarely there is pain if regeneration does not occur. The author has knowledge of three cases of fracture in the bone from which the transplant was removed, one in a child on whom an Albee operation was performed for tuberculous spine. Three weeks after operation the nurse in dressing the child, who had on a body cast, in turning it over hyperextended the leg which had been used for graft material, and a fracture through the site of removal followed. The second case followed an operation for an intramedullary graft for spiral fracture of the tibia in an adult man. Two weeks after the operation, when he had been allowed up in a wheel chair, he slipped in getting from the bed into the chair, and in the effort to spare the fractured leg and save himself, threw all his weight onto the leg from which the graft had been taken, and a fracture of that tibia resulted.

The third case occurred about ten months after the splint had been removed. The gutter had not filled in.

The use of the fibula has been advocated by several men on account of its size and complete covering with periosteum. This is not the bone of selection, however, by a large majority, except in some instances of bone loss due to other causes than fracture. Gangolphe and Bertein[2] suggest its use in comminuted fractures, but unless there is some necessity for employing the fibula the tibia is the bone of choice. Even in transplants for loss of bone Murphy suggests that this bone is not inherently large and consequently will not come up to expectations. Lewis[3] and others prefer to use the anterolateral surface of the tibia from which to take the bone splint. If possible the bone peg should contain all three elements of osseous tissue, periosteum, compacta, and endosteum.

The intramedullary autogenous bone peg comes very near fulfilling the requirements of an ideal fixation for fracture but it fails in some instances and we are forced to fall back on normal natural callus formation as the surest repair. In the last few months I have seen 3 cases of refracture through an old site repaired by intramedullary peg. One in the neck, one in the shaft of the femur and one in the tibia. These cases were asepic and the roentgenogram showed plenty of calcified callus about the fracture site. The bone pegs had been broken off at the point where they crossed the fracture line Certain rules of bone-peg insertion remain to be worked out based on experimental

[1] Jour. Am. Orthop. Assn., 1914, p. 299.
[2] Lyon, Chir., xi, No. 6.
[3] Surg., Gynec. and Obst., xx, No. 6, p. 631.

and clinical findings. The most important of these, omitting asepsis, I believe is the degree of tightness with which the peg is tamped into the medullary cavity and the amount of preliminary destructive reaming out of the medullary cavity. These two points have great influence on the subsequent blood supply of the peg and the formation of internal callus. For these reasons the inlay transplant, fitted snugly into the gutter cut out of the fragments, opposing like bone elements of the transplant in those of the bone fractured, becomes the anatomical and physiological method of treatment.

In the use of nails or ivory pegs as internal splints, particularly near joints, the same rigorous asepsis is followed. Incision should be long enough to insure complete reposition of fragments and the nail driven through the most dependent portion of the loose fragment diagonally toward the shaft of the bone to which it is to be attached. Way may be made for it by drilling, but this is not so necessary with silver-plated wire nails as it is with ivory nails. Either kind may be driven in as far as wished and then cut off flush with the bone surface.

Ivory pegs are useful and undoubtedly are ultimately absorbed. Where there is any fear of irritation from metal nails, or when there is proximity to a joint where a secondary operation for removal is not wished, ivory offers a good substitute for metal. The pegs are strong and will stand pounding in deeply if a hole is prepared for them by a drill. The ivory plate and screws offer the advantage that they are ultimately absorbed and cause quite firm fixation but really have little advantage over the steel plates and cost much more. Magnuson[1] and Brougham and Ecke[2] have advocated them. The author prefers to sterilize them by boiling for twenty minutes and then keeping them for many weeks in a strong solution of alcoholic bichloride of mercury. This permeates them and does not seem to injure their strength.

Unopened fractures that have healed in malposition and demand open operation are cared for by the same technic. When the site of fracture is exposed excess callus is chiselled off after reflection of the periosteum, and then the line of fracture is cut through. Placing the fragments in proper alignment, closing the periosteum down on the shaft and applying the Lane plate give excellent results. On account of muscular contraction of long standing some limbs cannot be extended or straightened out by mechanical means or tenotomy. In such rare cases the ends of the fragments will have to be cut off to allow for shortening. Intramedullary splinting is also applicable to these cases. Ununited fractures with and without pseudarthrosis, are primary indication for open operation. If a non-union does not yield to ambulatory treatment, to the pounding method of Thomas and Jones, or to other efforts, it is opened with the operative technic. Should no fascia, muscles or periosteum lie between the bone ends and the alignment be satisfactory, union may be stimulated by the driving

[1] Jour. Am. Med. Assn., lxi, 1514.
[2] Surg., Gynec. and Obst., May, 1914.

of a drill between the loosely joined fragment ends. However, when the field is open, if one will clear off the bone ends with a sharp chisel, it is surprising how often interposition of these tissues is found which is not apparent from the view obtained through the incision. As long as one is right in the area the best treatment is to freshen the ends and employ simple reposition of fragments with a slight shortening, or put in an intramedullary splint of such length and shape that the length of the leg is maintained. Plates should never be used when non-union or fibrous union is present. At the Hospital of the Good Shepherd they have almost abandoned the use of the Lane plates after twelve years' experience.[1] They found that the failure to get reduction was on account of the interposition of extraneous tissues between bone ends, and that external splinting did not offer good results on account of improper reduction and not because of muscular pull. Consequently they practice open operation with simple reduction and subsequently long immobility. MacAusland[2] favors simple reposition and cuts a small notch in the ends of the fragments if they tend to slip apart. Nails may be used merely as mechanical fixation to bring the freshened bone surfaces into firm apposition. Simple replacement by open operation should be given more attention than it has received. Removing interposing tissue and perfecting alignment in serrated or non-torsion fractures, gives good results. The operation is quickly done, and no foreign material is left, unless in some cases the fragments are tied together by heavy catgut or kangaroo tendon.

Other Types of Operative Treatment.—It has been suggested by Morris[3] that fractures be treated by pinning through a cannula with the aid of a fluoroscopic screen. This work demands a special table with slides which permit any part of the patient to be exposed to the Roentgen rays in front of a fluoroscopic screen. The operation is done under local or general anesthesia, the cannula is inserted obliquely through the skin and a drill hole is made to prepare for the dowel pin. This pin is inserted and tamped down after which the cannula is withdrawn. The skin is closed and an external splint is applied. I do not see what advantage this method has over nailing by open operation through a small skin incision. Morris admits that an error in insertion is possible, because the pin may be shoved along the shaft of the bone and may not fix the fragment as desired. One is more certain to see or feel these conditions through a small opening than through the fluoroscope.

Bradford and Soutter[4] advocate the fixation of fractured bone of infants by drilling through the bones subcutaneously by means of a long drill with an eye at the point which is thrust out through the skin on the opposite side to its entrance. Strong catgut is threaded into the eye of the drill and pulled through the bone by withdrawal

[1] Van Duyn, Am. Jour. Surg., xxviii, No. 1, p. 8.
[2] Surg., Gynec. and Obst., xix, No. 3, p. 404.
[3] Jour. Am. Med. Assn., lvii, No. 17, p. 1345.
[4] Boston Med. and Surg. Jour., clxxii, No. 14.

of the instrument. As many catgut strands are inserted as needed, the bony fragments are coapted and the strands are tied over a sterilized leather splint which stiffens in position. Other external splints are used in addition.

Various clamps have been suggested for use in ununited fractures, some of which are inserted around the fragments, left a varying period, and then withdrawn. Morrison[1] devised a clamp with five pointed teeth which was applied to the bone by open operation, and the handles were then withdrawn, leaving the clamp *in situ*. After five to eight weeks, by means of a small incision and rocking of the clamps they were removed, the secondary wound healing in a few days. The five cases he reported gave no trouble from infection. Another clamp on this order has been proposed by Simmons.[2] Ununited fractures are unpromising; the autogenous bone graft is the best treatment if the patient can withstand the shock of the operation. In the femur this is an important factor. Menton and Barton[3] cite a case in a boy of an open fracture of the femur which healed after infection with two and one-half inches shortening, but operation was refused on account of the danger from shock. Traction in a limb may cause rapid fall in blood-pressure.

In pseudarthrosis development between fractured ends, nothing short of the most complete exposure with dissection of the lining and covering of the false joint is of avail. Sharp dissection will remove every trace of a false joint and then the bone end should be sawed off, healthful fresh medulla exposed and a suitable intramedullary splint transplanted. These cases require an extra long immobilization of ten weeks or more, depending on the bone involved.

Ununited Fracture.—The Inlay Bone Graft.—In his paper before the Congress of German Surgeons in April, 1914, Albee gave a resumé of 250 cases in which he had used the bone graft.[4] Most of these cases were in Pott's disease of the spine, but he mentions one case of spinal fracture without displacement or cord pressure which was cured by inlay bone graft, as in his operation for Pott's disease. He believes that the Lane plate is a hindrance to bony union in ununited fractures, but that fresh fractures demand temporary fixation only, because the fragments are osteogenetically active and the plate in suitable cases fulfils this requirement admirably. For ununited fractures the problem is different, as here one has to deal with bone sclerosis, rounded ends, and medullary cavities plugged with osseous material, as described in the chapter on Pathology. The bone graft, which contains both periosteum and endosteum and is a bone unit in itself, makes the ideal repair for this condition. Albee's method consists in sawing a long slot out of the shaft of the tibia by means

[1] Ann. of Surg., l, 1114.
[2] Boston Med. and Surg. Jour., clxii, 174.
[3] Tr. Am. Surg. Assn., xxx.
[4] Surg., Gynec. and Obst., 1914; Am. Jour. of Surg., xxviii, No. 1, p. 26: Ztschr. f. Orthop. Chir., abstracted in the Jour. Am. Med. Assn., September 9. 1911; Folder, Am. Orthop. Assn., May 15, 1911, etc.

of a two-bladed saw. This graft contains these elements and can be slid past the freshened line of fracture and held in place by dowel pins of bone inserted on the edges. (See schematic figure in the chapter on Fractures of the Bones of the Leg.) In 17 cases of ununited fracture he has obtained bone union every time by using the inlay graft. The principle of autogenous bone splints in ununited fracture is sound, because this graft is living tissue which has some resistance to bacterial infection, and it becomes fixed in the new bed made for it. By its presence it stimulates bone formation and probably also takes on some bone growth itself in the periosteal layers. Other surgeons have reported series of cases treated by both the intramedullary and the inlay methods. Henderson[1] cites 32 cases of ununited fracture with satisfactory results. Five failures occurred, 2 each in the neck of the femur and in the humerus and 1 in the forearm. The other 27 obtained good functional results. He believes that the inlay method is better than the intramedullary, as the various bone elements of the graft are placed in contact with the corresponding elements of the fragments; that is, periosteum to periosteum, and cortex to cortex. Asepsis is as desirable in this operation as in plating, and the grafts must be autogenous and as a rule grow better in young than old individuals. The ingrowth of new capillary structures from the fragments into the graft must be preserved by a long and complete immobilization, because very slight movements which involve the graft cause these vascular connections to be ruptured and their renewal is necessary for a successful result. If they are broken up many times it is but reasonable to expect that the capillary proliferation will become discouraged and finally cease, or the graft be deprived of serum so long that it will begin to undergo atrophy or necrosis.

In fresh fractures the method of transposing the two strips of bone cut from the site of fracture has the advantage of obviating the need of opening the other shin for a graft. The grafts are cut wedge-shaped, wider on the periosteal than the endosteal surface, so that they will not slip into the medullary cavity and are changed about in accordance with that fact. They can be held in by sutures of kanagroo tendon applied through drill holes in the fragments or by small bone dowels as mentioned above. Albee says: "The grafts are removed from the fragments by starting the cuts with the twin motor saw adjusted to about seven-sixteenths inch (11.1 mm.) apart in a femur, then completing the cuts through the cortex to the marrow cavity with a single motor saw. The longer strip of bone is then inserted into the gutter so that half of it is in one fragment and half in the other.

"Dowels are now turned out with the motor doweling instrument, using for this purpose either the shorter strip of bone or bone removed from the side of the gutter distal from point of fracture. The graft is then forced into place and four holes drilled obliquely to its side

[1] Jour.-Lancet, xxxiv, No. 73.

and considers it particularly valuable in open fractures which have healed. Its troublesome aspects, according to him, are:

1. It may crack the compacta.
2. It holds poorly in the epiphyses or in friable pieces.
3. Near joints there is not enough space to place two nails on the juxta articular fragment.
4. A hole is left which invites infection.
5. Maintenance of fixation on the arm is very difficult.

He says: "Une fracture suturée n'est pas une fracture guérie," which might be translated to mean that the suture has no other purpose than to facilitate the natural course of healing, to assume its regularity, and to maintain the contact of the fragments. Dujarier favors wires which are put on encircling the bone fragments and removed after thirty or forty days. In the contemporary French Surgery department of the *British Surgical Journal*,[1] Prof. Tuffier states that "we have completely given up the use of bone staples and employ plates and screws of many patterns."

Recently Allen[2] recommends an external plate of an alloy metal poured and cast over the heads of nails whose shafts penetrate the two layers of compacta. When union is complete this cast is melted off and the nails drawn out. Good, strong nails or drills are used, inserted not in a straight line like screws in a plate, and a low melting alloy is moulded over their heads after the fracture is opened and reduced. This method seems far more elaborate than the Steinmann method or that of simple open replacement.

Robert Jones has said[3] "Before we reach the new things we must ask ourselves if we have done the best by the old; and it is only by being critics of our own work that we can discover each for himself which procedure will in his own hands give the best results."

[1] Vol. ii, No. 5, p. 157.
[2] Indiana State Med. Assn. Jour., 1914.
[3] British Med. Jour., December 7, 1912.

CHAPTER VII.

DISLOCATIONS.

Definitions and Classification.—A dislocation or luxation is a complete displacement of an articular surface from the other surfaces or bones which form a joint. If the displacement is not complete, so that the joint surfaces remain in partial contact, the condition is called a *subluxation*. Diastasis is a term applied to separation of two bones closely attached to each other without a true joint. A tearing apart without lateral gliding is understood. Examples are separation of the radius and ulna at the wrist, or the lateral separation of the pubic bones at the symphysis. Distraction is an injury in which the joint surfaces have been pulled from each other without rupture of the ligaments which bind them or change of their axial relationship. Some separations of the vertebral bodies fulfill these conditions. Sprains and distortions are caused by forcible wrenching of joints. Ligaments and capsules rarely stretch; most of the injury is caused by tears of fibers or by the pulling out of minute areas of the bone surface at the insertions of the ligament. The relationship of the joint surfaces is not disturbed permanently, though there may have existed a momentary subluxation which sprang back into normal position.

Dislocations are also classified as open or closed. When the joint cavity remains unruptured to the outside air it is called closed, and when the tissues are open to the air, open. Recurrent or habitual dislocation is a term which applies to those conditions which recur upon slight trauma or muscular action, generally aided by concomitant fracture and a defect or laxness in the ligaments and capsule. Dislocation of a joint which is healing after reduction of a recent dislocation does not constitute a recurrent dislocation. It is only when the trauma is trivial or a certain change of position easily induces the luxation that it is put in the habitual class.

Spontaneous dislocations are induced by pathological changes in the bone or joint and are really pathological dislocations. They are caused by slight force and muscle action or simply by gravity and may occur with a patient lying in bed. Congenital dislocations, strictly speaking, are those which exist in intra-uterine life on account of anatomical defects. Practically this term is applied to many dislocations which occur during delivery or very early in life from infantile paralysis, because it is difficult to ascertain the exact time of origin of the luxation.

Multiple dislocations are those in which two or more bones are dislocated simultaneously. They must not be confused with total

dislocations, a term which implies that a bone is luxated at the joints of both extremities. (See Dislocations of the Clavicle.) Bilateral dislocations are double dislocations; that is, the corresponding joints on each side of the body are dislocated simultaneously. There is no settled nomenclature descriptive of dislocations. Involvement of the large joints, as the knee or hip, are spoken of as dislocations of those joints, and the *distal* bones are the ones which are meant as being dislocated. Further to clarify the type of dislocation, it is customary to add the direction the dislocated bones take. For example, at the knee one speaks of dislocation of the knee forward, backward, or laterally in or out, meaning that the distal bones, the tibia and fibula, are carried in the direction indicated. When one or both bones in the limb are mentioned as dislocated, it is customary to speak of dislocation of the radius forward at the elbow or at the wrist, or to use the anatomical names of the portion of the bone displaced, so that no doubt will exist in the reader's mind. (See Occurrence of Dislocations.)

Stimson states that dislocations as compared to fractures occur in the proportion of about one to ten. During a period of collection of fracture statistics at the Cook County Hospital based on 11,302 cases, 775 dislocations were cared for. There was a slightly higher proportion of dislocations in the winter period. Of 775 cases, 690 were in males, 85 in females; 87 dislocations were in children, 69 male children being injured to 18 female children. Of the total number of dislocations, 409, or 52.8 per cent., were of the humerus. In accordance with the statistics of the previously mentioned cases, the fourth decade of life contains most dislocations, the fifth, sixth, third, seventh, second, first, eighth and ninth following in order.

Etiology and Mechanism.—Most dislocations are produced by external violence or muscular action and are consequently traumatic. The small proportion which are spontaneous are really pathological and are induced by changes existing in the bones or articular structures.

The causes of dislocation are divided between predisposing and exciting.

Certain predisposing conditions favor dislocation. The fact that there is motion in joints, that bone ends are held in contact by air pressure and surrounding structures, and that they are exposed to traumatic injuries which tend to overreach the physiological limits of motion, all tend toward dislocation. The action of powerful muscles across joints, effusions and hemorrhages into joints, which distend a cavity usually empty and weaken its soft structures, slow unnoticed pathological changes and fractures of associated bones, are also factors in production of dislocation.

The exciting causes are external violence of either direct or indirect character and muscular action.

1. **External Direct Violence is a Rare Cause.**—To cause dislocation in a healthy joint, direct violence must be so applied to the bone as to cause its holding ligaments first to give through being torn and thus

to allow the bone to be pushed from the joint. Powerful direct blows on the front of the humerus head may tear the capsular ligaments and drive the bone directly back under the scapular spine. Falls may accomplish the same result. Neighboring bony structures which interfere with this exitus may be fractured, or they may be broken first and the continuance of the force may drive the dislocated bone into displacement. The fibrous ligaments are quite inelastic; the displaced bone tears them apart, and all that is needed for reduction of the displacement is the pushing of the bone back through the same opening. Unfortunately the muscles or tendons which pass over the joint interfere with this procedure, and their action has to be reckoned with. Dislocations caused by direct violence which ruptures all restraint are easily reduced and also easily slip out of place again.

Dislocations caused by indirect external violence are very common and are more difficult to reduce because the *bone is not displaced in direct line of the trauma.* The principle of leverage enters into these dislocations, as the force acts at one end of the bone and the dislocation occurs at the other end.

Joints are divided into sliding, hinge, and rotatory, of which the hinge joints, represented by the phalanges of feet and hands, elbows, ankles and knees, are the more numerous. Leverage action does not have much influence on sliding joints, which are displaced laterally from each other. In hinge and rotatory joints we find most often a lever action on a bony or ligamentous projection as a fulcrum. The three types of levers must be remembered: (1) The fulcrum is between the power and the resistance; (2) the resistance is between the power and the fulcrum; (3) the power is between the resistance and the fulcrum. The mechanism of the first class, the fulcrum represented by a bony point or a strong ligament lying between the power applied at one extremity of the bone and the resistance of ligaments at the other end, covers most of the dislocations of long bones. The second and third class levers represent the dislocations caused by direct violence, because in these two classes the power and resistance move in the same general direction. Leverage mechanism of the first class is found in joints subjected to indirect violence in which the normal extent of motion is reached, or in which by reason of ligament restraint no further motion is possible because bony joints infringe on each other. When joints are flexed, there is no strain on them, because their movement is checked by the interposition of soft parts. When they are placed in extension, however, the checking restraint is either ligaments or ligaments plus a projecting point of bone or an articular cavity. If the indirect violence forces motion beyond normal limits after the ligaments are made tense, the fulcrum exists in the ligament or bone mentioned, and the resistance of the ligaments is overcome, the bone being displaced into dislocation. Violence, either direct or indirect, acting on a joint in a direction in which motion is not permitted, as lateral motion at the knee, may produce a dislocation, but the force applied must be much

greater than that which causes ordinary dislocation, and fracture often accompanies.

In specific types of joints the mechanism is as follows: For the phalangeal joints of the hands and feet as well as most of the metatarsal and metacarpophalangeal joints, the ligaments are situated in such a manner as to prevent extension much greater than a straight angle. If the distal end of the finger is bent backward suddenly, it acts as a lever of the first class, because its base presses against the proximal phalanx, which acts as a fulcrum, and when the ligaments on the palmar surface yield, the dislocation follows. Reduction is accomplished by flexing the overextended finger back into normal position. In some joints the tendons, muscles and fascia may interfere because of their mechanical presence, or because button holes have been punched in them which catch around the displaced bone ends.

The principle motion in ball-and-socket joints is abduction and adduction. The shoulder-joint has the greatest movement of all, because it articulates with the movable scapula and not with the rigid pelvis, as the femur does. Davis[1] says, "The consequence of this (motion) is that the traumatic force is diverted by the movements of the parts in response to the blow, and what appear like direct luxations are really indirect." Luxations of direct violence without the intervention of leverage action vary according to the direction of the injury, as has been stated, but indirect dislocations, in practically all of which the lever force is working, conform more or less to a type and are of regular character, because the lever action can become effective only when the distal part assumes a certain definite relationship to the proximal part and a fulcrum is supplied. In the chapter on the humerus there has been something said about abduction injuries at the shoulder. The abduction mechanism of this joint has been worked out by experiments on the cadaver and by clinical observation and can be easily verified. When the arm hangs at the side, or is brought forward across the chest, or is drawn backward, it always comes into contact with the trunk, and since there is therefore no fulcrum to act as an aid for dislocation, in these positions the arm cannot be dislocated. If the arm is abducted, a hyperabduction from trauma causes the tuberosity to impinge against the edge of the acromion, and a bony fulcrum is formed. The violence continues and ruptures the capsule on the opposite side of the joint and the head of the bone is pried out of the socket. The anterior inferior portion of the capsule is the site we would expect to be ruptured if leverage action is the cause, and this is found to be so. All other causes of shoulder dislocation are relatively rare.

2. **Muscular Action Causes some Dislocations.**—Tetanic contraction of one or a group of muscles acting unopposed by the muscles which normally counteract them may produce dislocation in a normal joint.

[1] Tr. Am. Surg. Assn., 1912, xxx, 588.

The muscular contraction may furnish the force which acts on the bone like indirect violence. The common example is dislocation of the lower jaw caused by muscular action while yawning or laughing. The humerus or tibia may be dislocated by sudden momentum transmitted to it by muscular action in violent kicks or efforts at throwing which miscarry. Voluntary power of dislocation is seen in some individuals. The proximal joint of the thumb is the one most commonly affected by volition. Such joint structures finally become quite lax. Some years ago a man of normal appearance made the rounds of the medical colleges who could voluntarily dislocate many of the large joints in his body. He had acquired the power by constant exertion and practice, using muscle contraction of certain groups over which he had an exact control. Some individuals can dislocate one or two joints voluntarily after having suffered a traumatic dislocation. The joint remains normal when the individual does not desire to throw it out of place. The tetanic muscular contractions of epileptic convulsions, strychnin poisoning, or tetanus may cause dislocation, although many of the reported cases are undoubtedly caused by the indirect violence of falls received in the convulsion.

The term *snapping* joint or *trigger* joint has been applied to a condition of subluxation of joints which is voluntary and caused by muscular contraction. The reduction is spontaneous, and the act of subluxation can be repeated over and over. The muscular jerk which pulls the head of the bone from the socket may be unconsciously performed or may be influenced by efforts to seek damages or to avoid military service. When the joint reduces itself there may be an audible snap, and the joint may be seen to jerk back into normal position. Almost any joint can be affected. Those most commonly found are the hip, shoulder, and knee. I have seen two cases in the thumb. Bertein[1] believes that the condition is a subluxation and that the peripheral snap of the bone is dependent on joint displacement, generally caused by a congenital or acquired laxness of the capsule. Worms[2] records a case of snapping shoulder-joint in a lad. He could produce a loud noise in the joint by outward rotation of the horizontally abducted arm. Two cases of snapping knee have been recorded by Billet.[3] These may arise from congenital arthritic changes or follow trauma and are very rare. Billet describes the mechanism as a permanently recurrent subluxation of the semilunar cartilages permitted by the laxness of the capsule and ligaments.

Snapping hip is recorded by Worms,[4] Coudray,[5] Müller[6] and Mouchet.[7] Mouchet[8] believes the condition is entirely voluntary.

[1] Rev. di Chir., August, 1914, p. 711.
[2] Rev. Med. de l'Est., 1914, Nr. 1, S. 18.
[3] Gaz. des Hosp. 86 année, No. 61, p. 997.
[4] Loc. cit.
[5] Arch. gen. de chir., 1914, viii, Nos. 3 and 4.
[6] Berl. klin. Wchnschr., 1914, p. 1210.
[7] Gaz. des Hosp. 87 année, No. 22, p. 349.
[8] Loc cit.

The characteristics of snapping joint are that motion in the joint affected is usually not limited. There is ease in producing the noise and subluxation by muscular contraction. The act can be repeated an indefinite number of times, reduction is easy and spontaneous, and the cause is some pathological laxness of the joint structures. As a rule the condition is painless. Various treatments have been suggested. Rest, electricity, baking, and operative treatment have been used. Excision of the joint cartilage or capsulorrhaphy have caused cures. Müller cured a snapping hip in a fifteen-year-old girl by applying a corset with a band around her thigh and a steel spring like a truss which made pressure behind the greater trochanter.

Habitual or recurrent dislocations are seen in the shoulder, jaw, and hip. They nearly always follow a traumatic luxation in which the joint has been distended and the capsule made lax. Paralysis of muscles which aid in the retention of the bones within the joint may contribute some help in the occurrence. They permit a laxness about the joint, and a slight trauma is all that is needed to throw the joint into displacement. The wearing away of protecting bone edges or their fracture, particularly of the glenoid rim, may also be of influence in recurrent dislocation. This class does not include the spontaneous dislocations, which generally remain permanent because the bones are pathologically affected, and while displacement occurs the condition is hardly a true dislocation. Unequal growth of two parallel bones may cause the dislocation of the faster growing one. This is seen in the forearm and leg.

Pathology.—In ball-and-socket joints exposed, as we have seen, to leverage action of luxation, the articular capsule and ligaments are torn quite uniformly to permit the head to escape. This tear may be a longitudinal or transverse slit. It may involve but a small part of the capsule or a large part of its circumference, or it may tear off the edges of the bone to which it is attached. Muscles inserted near the end of the dislocated bone may be torn from their attachment. The spinati muscles frequently tear out the greater tuberosity of the humerus in dislocations of the shoulder. In extreme violence the bone head may be pushed through other more remote muscles or even through the skin to the outside air, making open dislocation. Recurrent dislocations or traumatic dislocations, preceded by effusions within the joint or loss of tone in the periarticular structures, may permit the bone head to escape from the joint without tearing the capsule. The structures become so lax that the head will assume its new position, dragging its attaching ligament with it without tearing the capsule.

When other forms of joints are dislocated, the capsular structures may be torn completely around the joint or simply on one side. As a rule, the capsule is torn on the side toward which the bone is dislocated, but both sides may be lacerated and only a few shreds persist which hold the bones together. I have had a case of complete dislocation of a normal knee forward which gave no clinical evidence of

tearing the capsular structures. There was no hemorrhage or effusion in the joint, and after reduction there was little or no swelling in the knee. Another variation of the local pathology is for the capsular and other ligaments to remain intact, but the periosteum, which is continuous with the capsular ligament at its insertion, to be stripped off the bone and carried along with the dislocated end, leaving a space between it and the bared bone. This space quickly becomes filled with blood. Bony fragments of varying size may be lifted off with the periosteum. The articular cartilages are sometimes split or indented by pressure of the bone ends. Tags of capsular ligament or synovial membrane may come to lie between the joint surfaces. The edges of the bone or spines within the joint, as in the knee, are frequently broken.

The displacement of dislocations is rarely great. Strong muscular attachments, ligaments and tendons about joints, the softer parts, and the restriction of untorn parts of the capsule, forbid a great distance of separation. The position of the bone immediately after the dislocation is called the primary displacement. It often changes. The position finally assumed is termed the secondary displacement and is influenced by gravity, weight of a limb, swelling and edema, contraction of muscles, and the resistance of the untorn ligaments.

Pathological Complications.—These comprise local injuries of the bones, vessels, nerves, viscera and soft parts in open dislocation.

1. The bones are often injured in the manner previously described, whereby splinters are separated, periosteum is elevated, or an edge is cracked off. Though they are not serious complications, they really have a bearing on treatment and prognosis, and the surgeon should endeavor to diagnose their presence. A common example is the fracture of the tuberosity of the humerus. Breaking off of the edge of the glenoid or the acetabular rim is often overlooked and becomes a matter of considerable importance in after-treatment. Many cases of ankylosis or restricted joint motion are caused thus, the joint being used too early and too freely after reduction. Irritation is set up around the bone fragment and callus forms, often spreading out and involving the capsular ligament or causing an exostosis which hinders joint freedom.

The dislocated head may be indented, its cartilage may be split or denuded, or it may be fissured down into the shaft. These complications are not very troublesome, if they are recognized and the joint is given sufficient rest. The roentgenogram becomes of great assistance, taken after reduction. Rarely one bone of the joint formation is fractured to permit the dislocation. This is so in the hip in the so-called central dislocation of the femur, when the femur is driven through the acetabulum. Some dislocations are commonly associated with a near-by fracture, and the fracture is the primary injury rather than the dislocation. Fractures of the olecranon with dislocation of the head of the radius go together, and also some fractures of the shaft of the ulna with dislocation of the radial head. Dislocation and

fracture of part of one bone occurs in dislocations of the elbow, for example, fracture of the humeral condyle or the coronoid of the ulna being complications. The most serious complications of dislocation and fracture of the part dislocated is seen in the ball-and-socket joints, particularly the shoulder. As mentioned elsewhere, Mr. Robert Jones said some years ago that he had over forty roentgenograms of this condition. I have found it a rare complication in looking over hundreds of shoulder fractures. The usual place of fracture is through the surgical neck, rarely through the anatomical neck. Difficulty in reduction lies in exerting a reducing pull on the head fragment, which has been largely deprived of ligamentous attachments. There are some successful reductions by manipulation; most are operative. (See Fractures of the Neck of the Humerus.)

2. Bloodvessel injury rarely complicates dislocation. The vessels most often concerned are the brachial artery and vein or the popliteal vessels, and dislocations with great displacement are the cause. The tibial arteries have been injured in ankle dislocations, and in my case of dislocation of the tarsal scaphoid the dorsalis pedis artery was injured in its middle and inner coats, and its lumen was obliterated. In dislocation we do not find sharp or rough bony projections, which would tend to injure bloodvessels. The head of the humerus and the femur are round and smooth and do not rupture the vessels. At the shoulder the head of the humerus may tear the artery or vein or injure the inner coats of the artery so that a traumatic aneurism develops at once or within a few days. Gangrene of the arm may follow. Many of the bloodvessel complications of dislocation really follow efforts at reduction, especially if the time elapsed between injury and treatment has permitted adhesions to form between the ligament tags about the bone head and the vessels. Powerful traction or a fulcrum supplied by the surgeon's foot in the axilla may cause vessel rupture.

The symptoms of injury of large vessels are those of concealed hemorrhage. Fast pulse, shock, and paleness are prominent. At the site of dislocation a hematoma may form at once, which pulsates at first but gradually becomes tense and hard. If the axillary artery is ruptured, the radial ceases to beat, but it may also be affected by pressure on the axillary from a venous rupture. When the blood tumor is found well developed it is impossible to tell which vessel is injured, unless by some chance there remains a slight pulsation in the peripheral arteries, indicating that the arterial trunks retain continuity. Rupture of part of the vessel coats, leaving the adventitia leads to a more slowly growing tumor mass. This causes enlargement in the axilla, which may be mistaken for abscess or enlarged glands. Great care must be observed in cutting into such swelling about joints where there exists a previous history of trauma or dislocation. Dislocation may have been reduced either by a surgeon or spontaneously, the tumor mass causing symptoms later, possibly under the care of another surgeon.

3. Nerve complications are divided into three classes: (*a*) Traumatic neuritis which may occur without dislocation. Nerves may be contused or stretched by the dislocated bone and their impulse-conducting power temporarily abolished. They may be stretched, and hemorrhages into the sheath or between the axones may act to abolish transmission or to cause degeneration and subsequent paresis.

(*b*) Compression of nerve trunks between two bone surfaces by callus or by organized exudate and scar tissue. This is seen at the shoulder, elbow, and knee, especially about the head of the fibula, and a few other points. From the character of their cause these changes are generally late.

(*c*) Rupture or avulsion of a nerve or several trunks from the spine, as in dislocations at the shoulder. These are relatively uncommon and are often overlooked at the time of injury. The motor and sensory distribution in an extremity should be thoroughly tested after reduction of all dislocations.

The symptoms of nerve complications depend on the class in which they may lie. If a nerve or trunk is completely ruptured, there is complete permanent loss of motor and sensory power in its distribution. This is permanent unless plastic repair is performed. In the first class symptoms of pain, numbness, sensory and motor disturbance of varying degree are usually present. At first these are not marked. They gradually increase, especially if caused by pressure of misplaced bone ends which are not reduced. Traumatic neuritis tends to reach a culmination of its manifestations within six weeks, after which a progressive improvement begins.

4. The abdominal viscera may be injured by dislocation of the pelvic bones. The bladder is particularly prone to rupture. Central dislocation of the femur into the pelvic cavity likewise causes injury, and the spinal cord may be damaged when the vertebræ are dislocated. The esophagus and trachea have been opened or severely compressed by dislocation of the sternal end of the clavicle behind the sternum or the cornu of the hyoid bone. (See the chapter on these subjects.)

5. Open dislocations, especially those opened from within by tearing or pressure of the dislocated bone, are rare. The fingers are sometimes wrenched and pulled loose by an open dislocation which ruptures a phalangeal joint and tears away most of the soft parts covering it. These injuries result from violence which catches and holds the finger, or from sudden, sharp blows like that of a swiftly moving ball striking the end of the finger. Open dislocations of the larger joints are caused by extreme violence, generally accompanied by secondary twisting or wrenching after the dislocation has occurred. The skin opening may be produced at once by the outside force or from the bursting through of the dislocated bone head. These wounds are similar to those of open fracture, but in dislocation we have a joint surface exposed to outside contamination. As a rule, joint surfaces have less resistance to infection than bone, especially joint surfaces which have been suddenly snatched from a normal condition and

rudely opened to outside infections. Joints which have been traumatized and in the subsynovial layer of which a resistance has developed by a slow, low-grade inflammation have greater resistance. Open dislocations often lead to serious joint and bone infections. Amputations or complete excision of bones for necrosis and osteomyelitis follow. This is true in every case of dislocation of the astragalus that I have seen.

In the large joints the possibility of infection is great. Infection leads to pyarthrosis and probable destruction of joint surfaces, osteomyelitis, drainage, ankylosis, and possibly amputation. The prognosis is also grave, because these injuries are caused by great violence. Secondary opening may follow from pressure of the bone on the soft parts causing ischemia and local gangrene with sloughing.

Treatment of open dislocation is conservative. An effort is made to minimize infection by gentle cleansing or irrigation, and the dislocation is reduced. The wound is partly closed, drainage into an aseptic dressing being provided for. When infection starts, free drainage is indicated at once. If that fails to quiet the suppuration, resections of the joint or amputation are left.

Course and Repair of Reduced Dislocation.—As in the pathology of all traumata on living tissue, the repair rests on the extent of primary injury and the *course* of the dislocation after reduction of the periarticular structures. The usual course of reduced dislocation is simple, and the ultimate result is excellent functionally. The initial swelling is not great, especially if reduction has been accomplished soon after displacement. Pain and loss of function are also temporary, if the joint is given rest for a proper period that a normal surface condition may be regained, and the rupture of the capsule be permitted to heal. The amount of motion following dislocation is often left to the patient after a few days' immobilization, because no motion will be indulged in which produces pain or swelling interfering with use. A dislocated shoulder is put in a simple arm sling, and when the patient discovers that motions of use are painless and free they are indulged in to that range. Slowly full function is established. In some cases the periarticular structures have suffered considerable laceration, or there is greater hemorrhage, or some of the minor complications have taken place. Under these circumstances pain and swelling persist much longer, there is an inflammatory reaction, and rarely suppuration and abscess formation are present. The greater the inflammatory reaction the greater the restriction of motion will be from contractions of organized exudate about the joint, adhesions within the joints, and the binding of the periarticular muscle and tendons.

Secondary loss of function and pain may follow a course after reduction which appeared to be simple and satisfactory. This is comparable to an obscure and slow osteo-arthritis in which the changes have followed after the trauma of dislocation.

The course of open dislocations varies. Many of them which are

handled aseptically and promptly reduced lead to a primary healing of the soft parts. Others are infected, and all grades of suppuration in soft parts, joint, and bone result, with the consequences previously mentioned. The other complications involving bloodvessels, nerves, and bone change the course. Fracture especially leads to much loss of joint motion, through the misplacement of fragments or the formation of restricting callus. Fracture dislocation of the head and neck of a bone must first be considered as fracture, and efforts must be directed toward reduction of the fragments, which implies an incidental reduction of the dislocated head. Some fractures of an articular edge or an apophysis lead to irreducible and recurrent dislocation, a condition which may last during the patient's lifetime. The prognosis is good as to life, but if reduction is difficult, the chance for complete return of function is affected. The various complications, the joint involved, and the time after injury at which reduction is attempted all influence the reducibility.

The *repair* of dislocation must accord with the course. Dislocations undergoing repair *after reduction* are seldom seen by the surgeon, as no indication exists for open operation unless there should be suppuration, and then drainage alone is done. Most of our pathological knowledge comes from operations on recurrent or old unreduced dislocations. Rarely autopsy is performed on persons who have suffered traumatic dislocation and had an exitus during the course of healing of the dislocation. We expect local hemorrhage about the structures which have been stretched or torn by the luxation. This is seen clinically in the large ecchymoses which spread by gravity from shoulder dislocations. The joint may be filled with blood-clot or there may be but a small mass sealing the capsular tear. This tear as well as lacerations of other structures about the joint must heal by connective tissue, which cicatrizes and produces a scar. If the dislocation has been extreme, with any of the complications described, the resulting healing is an exaggeration of the simple process. The torn capsule may become adherent to vessels, muscles, or bone. The capsular structures become thickened as a result of violent attempts at reduction or motions indulged in before simple healing has taken place. Insufficient immobilization or early attempts to free the joint by painful passive motion have the same effect. All such adhesions cause restriction of motion. Infection and suppuration with their train of consequences are rare. The other complications involving fracture, nerve and bloodvessel injury have been enumerated and will be considered specifically under each dislocation discussed.

Recurrent and Old or Unreduced Dislocations.—Recurrent or habitual dislocation of the large joints are rare. They may follow an ordinary traumatic dislocation, but usually they are associated with some of the complications of luxation. Paralysis of muscle groups, laceration and incomplete repair of muscles important to the integrity of the joint, and acquired laxness of the capsule promote a tendency toward recurrence. A slight trauma or a position of the part which

throws strain on a weakened or lax side of the retaining capsule is all that is needed to permit the bone to slip out of the joint. The oftener this luxation occurs the more easily it luxates on subsequent occasions. The result is that the patient gradually restricts the use of the joint until all its motions remain within a safe limit, and it is only a rare unguarded movement during excitement that will result in another luxation. The recurrence may become so frequent that all pain and tenderness are lost, and the patient learns to make a reduction by directing his friends or by executing manipulations himself. On the other hand, especially in the shoulder, each recurrence may be as painful as the original luxation, probably on account of pressure on nerve trunks.

The pathology depends on the character of the original dislocation. Recurrence to the extent of causing an habitual condition is rare in normal joints. If the primary luxation has affected a joint poorly developed from the standpoint of its articular surface or of the enclosing ligaments, an unfortunate second trauma may start the articulation on the path of habitual luxation before complete healing has time to take place. Usually the rent in the capsule has not closed, or it has closed to leave a weak spot which bulges, or for a long time a joint effusion persists which also aids in distending the capsule. The loss of small pieces of bone which maintain a guarding edge of the articulation also favors an easy recurrence. If a small bone mass is split off and its periosteal attachment is torn, it gradually undergoes absorption and disappears, the edge from which it has been torn becoming rounded off. Recurrent dislocations which are based on paralyses are usually considered a matter of orthopedic treatment.

Old dislocations unreduced are serious problems and have a pathology quite distinct. Just when dislocation becomes an old dislocation which it is impossible to reduce by manipulation, depends on the individual case. Some joints become irreducible very quickly, depending on their size and the strength of muscles which pass over them or which maintain luxation by contraction. The local pathology about the joint also has an important bearing on the status of the luxation. Usually a joint begins to get into the class of old dislocation after four or five weeks, and before attempts at reduction are made the local conditions should be carefully ascertained. I have reduced shoulder dislocations five weeks old with no difficulty and in one three weeks out of joint I fractured the humerus by gentle manipulation. Reductive attempts should be without undue force and should aim to establish the possibility of the reducibility of the luxation without trying to accomplish reduction in spite of serious obstacles. If reduction cannot be made by safe procedures which will cause no additional damage, the case must be considered an operative one.

The pathology of unreduced dislocation concerns the capsular ligament and synovia and the soft parts surrounding the joint and bone with its cartilage. The first changes in the capsule are identical with those of dislocation which is reduced. There is capsular tear,

hemorrhage and extravasation into the joint and surrounding tissues, and in some cases small fractures, periosteal stripping, and cartilage injury. The dislocation remains unreduced because it is not recognized, or a complicating fracture exists, or because the attendant is unable to make a reduction under the circumstances in which the patient is treated. The fact that the dislocation is not reduced leads to a prolongation of the local reaction induced by the trauma, and secondary changes follow, caused by the changed relationship of the parts and efforts to create in the new position a surface which will take up the function of a joint. The tissues about the dislocated head become filled with extravasated blood from the lacerated vessels of torn capsule or muscles, pressure is exerted on all surrounding tissues, and the bruised parts are gradually infiltrated with small round cells. Blood is absorbed, the muscles are repaired by the granulation cells, and the whole area is surrounded by a fibrous capsule. Within the new fibrous capsule lies the displaced bone head. It is usually more or less free, permitting some of the ordinary movements of the joint, although they are greatly restricted, and is not adherent unless bare bone has been exposed by stripped periosteum and apophyseal splinters. The connective-tissue cells lining the fibrous capsule flatten, and by metaplasia assume the shape and appearance of cells lining a synovial cavity. The transition is similar to that in the formation of new joints when fibrous tissue is used in surgical arthoplasty. The original capsule may be continuous with the newly formed joint because, as previously mentioned, it is rarely completely torn off. Under some circumstances the bone head escapes through a tear in the capsule which closes valve-like around the neck, and the natural capsule remains more or less intact, minus the bone head, until secondary changes follow. These changes are obliteration by adhesions resulting from the trauma and the pressure of the surrounding parts on a surface no longer functionating.

Within the new capsule may be found a small amount of fluid. This may be secreted by regeneration of some of the synovial surface cells which have been carried into the lacerated area.

The outer surface of the fibrous capsule is usually adherent to the surrounding lacerated tissues. These are muscles and nerve and blood-vessel sheaths, and as the connective tissue ages this adherence becomes very firm and by its contracture may further restrict the joint movements or cause changes from pressure on the nerves and vessels. On account of the new position of the bone and the different muscle balance consequent upon it, the muscles crossing the joint or inserted in its vicinity undergo shortening or atrophy. This fact may be illustrated by a dislocation forward of the humerus at the shoulder. The great pectoral muscle, attempting to functionate, has to shorten its fibres, because the insertion in the displaced humerus has been brought nearer the origin on the chest. The muscle may also undergo some atrophy on account of its restricted use. The deltoid muscle may be stretched by the new position of the humerus, but as weeks

pass and the dislocation remains unreduced and abduction of the arm is greatly restricted, this muscle undergoes an atrophy.

The coincident bone and cartilage changes must also be understood. These can be discussed in the order of their occurrence as the luxation becomes old. Chips of bone broken off articular rims or raised up by stripped periosteum may proliferate or become absorbed, according to the retention of their blood supply and the amount of proliferative irritation they are subjected to by joint movements. Small exostoses may grow along the stripped periosteum or out into the fibrous capsules. A thick layer of new bone may be deposited beneath a raised periosteum and act as a restrictor of motion in the new false joint. A strong bridge of bone may be laid down along a periosteal shred to connect the two bones of the joint. That portion of the dislocated head or neck which comes to lie in contact with the other bone forming the joint is subjected to an unnatural pressure, the periosteum is eroded, and some absorption takes place in the area, so that a depression is formed. This is enhanced by an irritative proliferation at the edges which are attempting to offer support and stop the pressure, a slight ridge being built up about the absorbed part.

The whole shaft of the displaced bone also undergoes structural change similar to that following fracture. By means of serial roentgenograms taken week by week, as a dislocation remains unreduced, changes in the osseous structure can be seen. The bone becomes more transparent to the ray, the lamellæ are thinner, and there is undoubtedly a disturbance in the calcium equilibrium of that bone. These changes are in accordance with Wolff's law and arise from the altered and incomplete function of the luxated bone. These changes offer a partial explanation of the ease with which bones in old dislocations are broken when subjected to manipulation, and constitute a clinical point of importance. The cartilaginous surface of the head and the joint from which it has been removed undergo slow changes. When articular cartilage has been stripped or torn from the surface of the head, we may expect to find bone regenerated, a fact which is verified by examination of old dislocations at operation and autopsy. If the cartilage has not been injured, it tends to remain intact for an indefinite period. The joint surface slowly fills in with cartilage and soft bone and its contour becomes lost. This material ultimately ossifies and is cemented to the joint surface so firmly that it can be only removed by a sharp chisel. The elbow reacts more in this respect than other joints commonly dislocated, and the bony mass makes reduction impossible without a complete removal and reformation of the joint surfaces. The growth does not demand a great length of time. I have seen it become very extensive within three months after dislocation.

The final change about the unreduced bone head represents a natural reaction of the tissues to adapt themselves to new conditions and to aid function as much as possible. When use is attempted and the dislocated bone moves and the new joint begins to functionate within

its restricted limits, the neighboring bone structures are stimulated to build up a new cavity for joint purposes. This is best demonstrated in hip dislocations when the femoral head rides on the ilium. From the ilium bones develop, buttressing edges of which tend to form a new acetabulum about the head and furnish some stability to the new capsular ligament. These changes are all in response to functional use and are like those appearing in bone transplants which grow and assume the shape of the bone they replace as function progresses. A transplant inserted into the upper end of the humerus, one end lying free in the glenoid, will take on the shape of the former humeral head if it is used and the muscles are attached. The growth is a pure osseous structure, and is very firm, so that its removal requires cutting with sharp chisels. The process may become excessive and spread out into the new joint capsule enclosing the head and gradually produce a complete ankylosis.

Symptoms, Signs, and Diagnosis.—The symptoms and signs of dislocation are as closely interwoven as those of fracture, and they will be considered in the order of relative importance without an attempt to separate objective and subjective findings. The examination of the patient must be thorough and comparative. Not only must the joint which is complained of be carefully subjected to tests and local manipulation, but the corresponding normal joint must be used as a basis for comparison. This means that the patient should be exposed sufficiently to permit the free inspection of the joints considered, and every precaution must be taken to eliminate natural peculiarities and attempts at malingering. Diseased conditions which affect joints must be borne in mind constantly. The different arthropathies peculiar to diseases should be remembered. Tabes particularly is a stumbling-block.

The condition of bloodvessels and nerves in the limb should be ascertained and a written record made. This record is of assistance to the surgeon or a consultant, if the dislocation remains unreduced or complications appear which involve the enervations or blood supply. If the nerve supply to arm and hand is intact immediately after dislocation of a shoulder, so that the usual motions of the wrist and hand are possible, the surgeon can, if paralyses appear later, eliminate avulsion or rupture of branches of the brachial plexus and can attribute them to pressure or secondary causes. The same precaution is taken in regard to circulation. Radial pulse is searched for and its condition noted. These same records should be made after reduction to establish any causative relation between attempts at reduction and subsequent evidence of injury of these structures. (See History.)

Examination must determine the position of the head of the bone to the satisfaction of the surgeon. In most cases the position is both visible and palpable when the limb is manipulated. In others swelling, effusion about the joint, much adipose tissue, pain, or lack of coöperation by the patient may prevent definite information. The final expedients consist in obtaining a roentgenogram and in admin-

istering a general anesthetic for diagnostic purposes. The same statement made in regard to the use of anesthesia for diagnosing fractures should be made here. It should be employed in all doubtful cases, but when it is used its aid must also be extended to cover treatment, which the surgeon must be prepared to apply at the same sitting, regardless of the character of procedure needed. The roentgenogram is valuable in old dislocations for demonstrating the amount of secondary change about the joint. Fresh dislocations are not so often subjected to the rays, because diagnosis is not difficult and the patient's distress demands immediate reduction. Certain complications, especially accompanying fracture, are shown by the roentgenogram, and for that reason it is often the best procedure to have a picture before reductive attempts, in order to avoid unsuccessful manipulations which may be harmful on account of the fracture present.

A history of some sort is always obtained before diagnosis is ventured. The kind of violence and the position of the patient and the limb are inquired into. The character of the pain and subjective sensations of crepitus are often valuable to the surgeon. One must also be sure whether the joint has ever before been dislocated and whether the dislocation is one which can be caused voluntarily. Fracture is the first condition to be eliminated in differentiation, and the history will often help, especially if there has been a previous injury of one kind or other. In case of any doubt the roentgenogram and examination under anesthesia will be decisive. Usually one can palpate the dislocated ends sufficiently well to rule out fracture of a neck or shaft, but not well enough to disprove the smaller fractures of bone edges. Frequently also the swelling and extravasation are prompt enough to mask characteristic deformity, and any surgeon may be unable to make a definite diagnosis without the aids mentioned.

Deformity is apparent in most dislocations, and it is quite characteristic, as is also the patient's position. The location of the bones forming the joint is abnormal to a varying degree, and the exact position can be made out by palpation and a little manipulation. Most dislocations are quite rigid, and swelling does not appear at once to mask the preliminary findings. After a few hours the extravasation may fill out depressions or cause so much periarticular distention that the evidence obtained by inspection is altered. Some deeply seated joints are difficult to examine on account of the overlying mass of soft parts. When this condition is augmented by a hemorrhage into the tissues, recognition of the character of the injury is almost impossible through inspection and palpation alone. At the knee and elbow, dislocations are relatively easy to recognize by deformity. At the ankle, shoulder, and hip they are more difficult. The examination must be steadily urged after the patient's confidence is won. The head of the bone must be sought after one notes the position of the shaft or other well-known joints of the bone which furnish landmarks indicative of the usual location of the head. Slight

movements of the shaft are transmitted to the head unless there is fracture. If these movements are lacking in the space where the head normally lies, and are found in an abnormal position which other bony points indicate that the head has shifted to, one can be sure dislocation is present.

Shortening and lengthening deformity are also signs. Either one may be apparent and not real when measurements are used. The rigidity of the limb and the muscular spasm do not permit the symmetrical placing of corresponding limbs, and measurements fail to give exact information. The same precautions in regard to normal varying length of limbs given in the chapter on Fracture of the Femur must be used in all dislocations examined in this manner.

Loss of mobility and function are also important symptoms. These go hand-in-hand, the function depending on the changed mobility. Some complete dislocations retain a surprising amount of function and motility in the part, and the patient may be unaware that the joint has been disrupted. The subluxations are usually of this character, and function except in one or two special directions may be normal. Usually if function is little interfered with, there is also pain at this limit, and relief is sought on that account.

Loss of mobility depends on the joint dislocated. All typical luxations assume a position which is characteristic and is described under each dislocation discussed. When the bone head is thrust into an unnatural position and remains there, the limb axis changes, and a new centre for the arc of motions is established. The untorn portion of the ligaments is put on a stretch and fixes the dislocated head so that it cannot be moved farther away from their attachment without their rupture. Pain and muscle spasm also inhibit mobility. Muscles have less influence than the untorn, non-elastic ligaments, because their length has been altered by the new position and their contractive power is overbalanced. Their influence can be eliminated by the administration of anesthesia, but the ligamentous limitation cannot be so overcome, and the loss of mobility in dislocation is present in unconsciousness. This furnishes a basic differentiation between fracture and dislocation which is open to very few exceptions. Fracture usually presents excessive mobility, except in the few instances when the part is held more rigid, a reflex protective measure of the body on account of pain. A few dislocations also vary to permit an unusual amount of motion. They are accompanied by complete tearing of the capsule and generally by fracture.

Pain and Crepitus.—Sharp pain is present in a joint which suffers traumatic dislocation. It may be acute enough to cause collapse and vomiting. This pain continues for a few hours on account of the pressure at the joint and the extravasation, together with the stretching of the lacerated tissues. Usually it subsides within twenty-four hours to a bearable state, but is easily provoked by efforts at use or by manipulation. Tingling and burning pains or numbness referred distally to the dislocation indicate pressure on nerves by the head

of the bone. If this disturbance with muscular paralyses comes on late in the course of an unreduced dislocation, it may be surmised that a nerve trunk is included in scar tissue. Crepitus is sometimes found in dislocation. It is different from the sharp clicking of fractured bone surfaces and is probably caused by the neck of the dislocated bone moving against the edge of the opposite bone. A dislocated tendon, like the biceps tendon at the shoulder, may produce a sensation simulating crepitus when the arm is manipulated. The softness of the crepitus and the absence of other signs of fracture help differentiate the two conditions.

Treatment.—From the remarks made on etiology and mechanism of dislocation, it is evident that leverage action plays the most important part in causing traumatic dislocation, and that treatment which primarily aims to return the misplaced bone to its former position must reverse in part the conditions existing during the operation of the cause. The capsular ligament is seldom completely torn, and it is the traction of its untorn fibers which has much to do with holding the bone out of place. Efforts to reduce are divided into traction and manipulation.

1. Traction is the oldest method and is now little used, except in combination with manipulation. Force was applied manually in the long axis of a limb by the surgeon and his assistants, counter-pull being made on the trunk by one of them. In cases of hip dislocation mechanical extension was often used by means of a band around the leg and foot attached to the pulleys. Considerable force could be exerted to pull the head of the dislocated bone down toward its socket, and the surgeon then made pressure or manipulation on the head to force it into place. The force used in this type of reduction was so great that the bone was dragged back in spite of the resistance of untorn ligaments, and often damage additional to that of the original dislocation was done by the laceration of these remaining intact structures; nerves and bloodvessels were frequently torn; there was much shock, and suppuration resulted in the joints. The method did not take the mechanism of the cause of dislocation into consideration and was based on force rather than pathological knowledge of the usual tissue conditions about the joint. Often it succeeded with little difficulty, because the secondary displacement of the limb had not taken place and the head of the bone was pulled in the right direction to reënter the socket through the tear in the capsule. The capsule may also have been so widely torn that the head could be drawn into place without opposition.

Continuous traction by the attachment of India rubber bands or adhesive straps with weight and counter-extension is also an old method modified from the means of direct forcible traction. This method attempted to tire out the muscles about the shoulder, for instance, in dislocations involving that joint. A weight of twenty pounds was applied on a pulley with the arm in as much abduction as could be obtained, and after a few minutes when the contracted

muscles relaxed the head approached nearer the glenoid, the long axis of the arm assumed a more normal direction, and the reduction could be completed by the surgeon giving a sudden additional jerk or by pressing the humeral head at the shoulder into the socket. At the present time anesthesia accomplishes the relaxation with no pain and more quickly. Continuous traction was also made by the use of the unsupported weight of the limb. The patient lay on a table or bed in a manner which permitted the limb to hang and pull by its own weight until the muscular contraction was overcome and the head slipped into place. (See Dislocation of the Humerus.)

Manipulation has become the method of choice in treatment of traumatic dislocation. It is based on a better knowledge of the immediate pathology and seeks to restore the bone head by leverage which utilizes remaining ligaments as a fulcrum, does no additional lacerating damage to the capsule, and attempts to reënter the joint *via* the tear of exit. Each joint necessitates its own manipulations and a general statement only can be given here. Attempts to reduce by traction made in opposition to the restraining pull of the persisting ligaments are not performed, but the ligament is taken advantage of by moving of the limb in the direction in which this pull is exerted and by subsequent leverage using this attachment to help guide the head into position. The manipulations also aim to reopen the tear in the capsule so that the head easily slides back. Some traction is necessary that the spastic contraction of muscles may be overcome unless an anesthetic is used. Many luxations are reduced with ease; others present obstacles and demand repeated attempts with close attention to the detailed requirements for the joint under treatment.

An obstacle to reduction of recent uncomplicated luxation is found in the pain present, which results from the capsular and tissue damage or from nerve pressure. The pain is increased by manipulative efforts, and fear of it induces muscular contraction and lack of coöperation by the patient. Swelling about the joint from the extravasation may also hinder reduction, just as it interferes with reduction and its maintenance in fracture. If the fascial envelope about the joint is intact, the extravasated blood distends it in a transverse diameter, shortening the longitudinal, and preventing manipulative efforts to bring the head back into the joint. For that reason it is best to reduce a fresh luxation as soon as it is seen, before the swelling has reached a maximum. If it does furnish a real obstacle to reduction, the surgeon may wait a few days for its subsidence under cold applications, or give an immediate anesthesia. The subcutaneous fat of obese persons may offer an obstacle to reduction inasmuch as it interferes with the proper manipulation.

The rôle played by the ligamentous and capsular structures in obstructing reduction depends on the pull of the untorn portion, the site of the capsular tear, and the interposition of flaps or shreds between the head and the joint surface. Manipulation applied on a basis of

the pathology in the injured joint tries to utilize this pull as outlined, but the tear in the capsule may be of a character that brings a flap down over the joint surface and shuts the head out of the socket in spite of all efforts to spread it open that it may receive the bone. This type of dislocation is also found in the one in which the head is thrust completely out through the capsular tear, and the capsular slit closes completely behind it around the shaft. Dislocations caused by direct violence with great laceration or complete tearing of the capsule are very mobile, and the absence of ligamentous restraint permits an easy reduction by direct traction. The two types can be differentiated by the greater mobility in the form caused by direct violence and the reduction may be quickly performed without much manipulative effort.

In some cases of dislocation of the smaller joints a muscle may be penetrated, or a tendon may wrap itself about a dislocated bone end and obstruct reduction. Concomitant fractures of the neck or shaft of a bone, small fragments split off the cartilage or the other bone forming the joint, also offer obstacles to reduction.

The complications of reduction or attempts at reduction are divided into immediate and delayed. This division of complications is selected because it fits pathological conditions as we now understand them and does not depend on irrational treatment. Many of the complications of forcible reduction of dislocations which were common twenty-five years ago are seldom seen at this time on account of prompter reduction, often under anesthesia, the checking use of the roentgenogram afterward, and a more intelligent early operative interference. The complications and dangers incident to general anesthesia, the remote sequelæ of surgical procedure which occur after any operation, and the unforseen troubles which arise after traumatic accidents cannot all be attributed to dislocation alone. Many of these conditions have been discussed fully in the chapter on the Pathology of Fractures, and only those which are of special interest in connection with dislocation will be described here.

The immediate complications of reductive efforts are injury (1) to the bloodvessels, (2) injury to nerves, (3) fracture, (4) rupture of muscles, fat embolism and sudden death, (5) avulsion of a limb and (6) damage to the skin. Delayed complications consist in late manifestation of injury to bloodvessels, nerves and lymphatics, resulting in paralyses, persistent edema or late gangrene, infection and suppuration in the joint, and ankylosis.

Injury of bloodvessels in dislocations which are promptly reduced is rare. Confusion arises as to the cause. Probably over half are caused by the trauma of dislocation and the symptoms do not appear until just after the early reduction. For that reason the condition of the distal arterial supply should be ascertained in every case before efforts at reduction are undertaken. These injuries occur more frequently in elderly people, especially those with stiffened arteries, and in cases where repeated and forcible efforts have been made at

reduction. Hessmann[1] reported rupture of an axillary artery in a seventy-two-year-old man, and Körte[2] reported 4 cases and made a collection of over 40 others. Most of the main bloodvessel injuries occur at the shoulder. At the knee, elbow, ankle, and hip they are rare, and the recent literature of dislocations contains little reference to them, on account of change in methods of reduction, and the greater frequency of open operation. Wild and repeated efforts at reduction should be avoided, especially when the patient is under anesthesia. The primary injury of the dislocation may partly tear through the wall of a large vessel; a traumatic aneurism with a sac may slowly develop and the vigorous movements of reduction cause it to burst. The dislocation may tear off small branches of a main artery and lead to the formation of a slowly forming blood mass. This may be mistaken for abscess and be incised. In old dislocations, adherence of ligaments or bone to the vessel wall causes a tearing when violent efforts are made to free the structures. Dislocations of long standing are accompanied by shortening of the vessels or increased local rigidity. Adherence is more likely to injure the thin-walled vein than it is the artery. Hyperabduction of an arm after many weeks of confined position in dislocation easily injures the vessels. Bone pressure in an abnormal position against a large pulsating artery may gradually weaken the vessel wall, and reductive force adds the finishing touch.

The symptoms of immediate injury of important bloodvessels during reductive attempts are pain, shock, formation of a rapidly growing, diffuse tumor near the dislocated joint on which the efforts have been made at reduction. Almost all the reported cases concern the shoulder and the axillary vessels. The tumor is fluctuating, occupies the axilla, even bulging out behind, and over it may be heard or felt a bruit. The distal pulse may or may not disappear. If the patient survives the rupture, a wide-spreading ecchymosis appears on the chest and shoulder. Some ruptures cause death within a short time before any treatment can be attempted. When a small vessel is injured, the mass of hemorrhage may be of slow growth and reach a stationary point. This rupture is caused by the immediate effects of the efforts at reduction, but its appearance may be late. Theoretically the surgeon would expect to differentiate between arterial and venous rupture by the color of the distal part, the presence,or absence of pulsation in the distal vessels, and the bruit in the aneurismal mass. Practically this is difficult or impossible to do. Though the main injury may be venous, the mass may transmit the underlying arterial pulsation, or a small arterial branch may be ruptured nearby and lend its pulsation by hydrostatic pressure to the whole liquid tumor.

The treatment of vessel injury depends on its gravity. If a slowly growing mass becomes evident after reduction, pressure and cold may stop its progress. Arterial rupture is very serious at the shoulder, and the surgeon must decide whether it is better to operate early in

[1] Münch. med. Wchnschr., 1905, No. 42.
[2] Arch. f. klin. Chir., xxvii, 631; ibid., lxvi.

the face of a small blood tumor, tie the vessel, and attempt its repair, or wait until collateral circulation has had an opportunity to enlarge and then close the main vessel by ligature. Modern surgery leans toward early operation with repair of the lateral wall of the vessel, transplantation of an autogenous piece of vein, or endo-aneurismorrhaphy. If these fail and gangrene ensues, amputation is the only recourse.

Injuries to nerves are not common during reduction of recent dislocations. Most instances occur at the shoulder on account of the proximity of the brachial plexus to the shoulder region. The circumflex nerve alone or whole branches of the brachial plexus may be injured from bone pressure or tearing adhesions. At the elbow, the ulnar, median, and radial nerve may be involved, particularly in dislocation of some standing. I have seen one case of injury to the ulnar and one of the median. In the leg, nerve complications are rare; rarely the sciatic has been involved in hip dislocations, and the external peroneal in dislocations of the head of the fibula. In these cases there is always difficulty in decision as to whether the nerve complication belongs to the dislocation or the reduction; hence the value of careful observation before reductive attempts.

Fracture also results as a reduction complication when unwise force or forced position is attempted. The neck of the humerus may be broken by leverage with a foot in the axilla. I have seen one case. Abduction and rotary motions may fracture the shaft spirally, as in one of my own cases. I have also seen the lesser trochanter of the femur pulled out twice in efforts at reduction of dislocated hips. At the elbow the lower end of the humerus may be broken. On the whole, the accident is rare. The instances are not, however, confined to old dislocations. Muscle rupture is also uncommon. Muscle shortening following dislocation may lead to a tearing out of its bony insertion when extreme attempts at reduction are practised, but rupture of the belly of the muscle is practically never seen. At the shoulder the spinati or subcapsular muscles may be lacerated. The neck of the humerus will always break before the pectoral muscle is torn.

Avulsion of a limb has been recorded as a complication of reduction. Guibé[1] collected 49 cases. Probably most cases have underlying pathological changes which were not noted at the time, involving bone and soft parts. Syphilis, carcinoma, sarcoma, and degenerative changes, softening in character, may favor such an unhappy termination.

Skin complications of reduction consist in tearing or lacerations from cords used for traction, or pressure necrosis following prolonged constriction. Severe pressure over a block or the pressure of an unpadded Thomas wrench may cause skin necrosis. The use of mechanical traction must be guarded by heavy pads about an ankle. Saddler's felt is the best material.

[1] Rev. de Chir., 1911, xliv, 581.

Sudden death during manipulations of reduction may be caused by shock, hemorrhage, embolism, or anesthesia. They are infrequently seen. If fracture accompanies the dislocation, fat embolism must be considered following the manipulation of the bone fragments in reduction.

The delayed complications are the late bloodvessel and nerve complications, infection with suppuration, and sometimes gangrene and ankylosis. The bloodvessel and nerve conditions are described under the immediate complications. Infection rarely follows present-day methods of reducing closed dislocation. I have never seen a case. Great extravasation about a joint may cause pressure necrosis through the skin with secondary infection, or the trauma of reduction may cause the location in the joint of wandering infections from the blood stream. Gangrene may follow from pressure of the inflammatory mass, or late infection. Edema from interrupted venous or lymphatic drainage may persist as a late complication from reduction. Ankylosis partly caused by traumatization of the joint surface in forcible reduction, or the processes inaugurated by the dislocation may follow any reduced dislocation. This ankylosis may be from intra-articular or periarticular changes, the former being set up by irritation of the synovial surface with the possible aid of bacterial invasion from the blood stream, the latter from ligamentous contraction and the formation of bony outgrowths from torn periosteum and wandering osteoblasts.

Operative treatment of recent dislocations is broadly indicated when the obstacles mentioned are not overcome even under anesthesia. Arthrotomy is indicated when the displacement is unusual and there is some interposition of muscle, fascia, or ligament. It is also indicated when cartilaginous and bone fragments obstruct, or a tendon is inextricably wound about the bone. A generous incision over the part of the joint suspected of blocking reduction is made under the usual aseptic precautions, and the obstacle is snipped through or slid over until the bone can be returned to the socket. A minimum amount of operative procedure is undertaken, and if the capsular rent is not great and does not tend to fall into the joint, it need not be sutured at all. An immediate arthrotomy before secondary infiltration and swelling is usually successful and remains clean. If swelling and secondary position have already occurred in the joint, it is better to wait a week or ten days for the absorption of the exudate and the resistance building of the leukocytic infiltration. The same problem arises as in repair of the fracture of the patella, and the immediate operation has as many adherents and happy results as the delayed, provided the skin condition and the asepsis are satisfactory.

Treatment of habitual dislocation is at first conservative and nonoperative. The joint is put at rest in a simple dressing for the upper extremity and a cast or Thomas splint for the hip and knee. The prolonged rest may cause a shrinking in the capsule or permit it to regain tone sufficient to prevent recurrence after the dressing is

removed. Slightly restricted function afterward, governed by straps or elastic supports, favors a normal joint function. Operative treatment is reserved for the stubborn cases. I cannot see the advisability of injecting irritating solutions into the joint. They undoubtedly cause an exudation which temporarily distends the joint and but weakens the capsule the more. An injection followed by immobilization for a period long enough to allow absorption of the exudation and retraction of the capsule might lead to an ankylosis. Irritating injections of formaldehyde in glycerin which are used for joint infections, produce a marked reaction, but do not lead to restriction of joint motion. It would seem more rational to employ *periarticular* injections of tincture of iodine or other solutions. The inflammatory reaction set up with immobilization should cause a cicatrization of the pericapsular fibrous tissue and ligaments and subsequently strengthen the joint. These methods are used clinically with success, especially in the jaw, shoulder, and clavicle. Stimson reported two cases of habitual clavicular dislocation cured by periarticular injections of alcohol.

Operative treatment aims to shorten the capsule by plication and to tauten by transposing of muscle and fascial flaps or by shortening of isolated muscles or groups of muscles which control the joint motions and permit the dislocation. These operations differ for the various joints. General principles concern the technic of narrowing the capsular structures. Rows of stitches can be inserted in one axis and, when drawn taut and tied, cause a capsular shortening in the opposite axis. The capsule can be pinched up, sewed together, and the lax portion plicated over by retaining stitches or cut off entirely. Muscles can be shortened by exsection of parts of their tendons or by moving and reattaching their insertions. Fascial flaps may be swung over a loose and weak part of a joint from neighboring tissues, or a transplantation of fascia from the thigh may be put on as a patch. These operations are performed without opening of the joint, unless there is a loose fragment of bone or cartilage which must be removed. When all methods fail and the recurrence causes provoking disability, an arthrodesis can be done.

Old unreduced dislocations cause much change about the joint, as has been described in their pathology. Treatment depends on the age and the evidence of bony and fibrous restriction about the dislocated bone ends. Many of them are accompanied by small fractures, as we have seen, and all are likely to have firm adhesions to the periosteum, and surrounding soft parts as well as bloodvessels and nerves. The muscular shortening and the filling in of normal joint cavities preclude reduction by manipulation and traction. Formerly strenuous efforts were made by forcible traction to pull these long displaced joints back into position. It is difficult to say just how much change has taken place around the joint in any given case, even by the aid of the roentgenogram, and each old dislocation should be subjected to *mild manipulative* and traction efforts before open opera-

tion is performed. Experience shows, however, that very few can be reduced by the means of manipulation, and of those which are forcibly brought back into position, a large proportion suffer injury to blood-vessels and nerves which is serious, or infection attacks the joint and causes the complication most feared of all. A certain small proportion escape these complications, but function is never satisfactory, and after the manipulative inflammatory reaction ankylosis frequently follows. A better functional position of a forearm and hand or any limb may be obtained often even though it is ankylosed. Although general indications may be laid down for operative attack of these old unreduced joints, each individual case must be judged on its own findings. It has been my experience that women make better patients than men for operative relief on joints. They have smaller bones and often more subcutaneous fat and are more persistent in efforts to obtain results for cosmetic reasons. A decision must often be made in certain joints, particularly the hip, between attempts to reduce the head into the acetabulum, excise it, or produce a bony ankylosis between the femoral neck and ilium. (See Fractures of the Neck of the Femur.) The problem of mobility *versus* strength must also be considered. Rigid strength is often of greater functional value in the hip or other joints than mobility, which would lead to pain and weakness after use. Pain from pressure on nerves or trophic disturbance resulting from the same cause is amenable to relief by operation. The danger of infection in the joints and the sloughing of tissue flaps must be weighed. Osteotomy below the trochanter of the femur or above the condyle of the humerus presents a chance for many functional improvements.

Surgeons prefer to treat these cases by arthrotomy. Each type of joint offers problems peculiar to its topography, and but few general remarks can be made covering the subject. The rules I follow are these: One incision only is used unless it is utterly impossible thus to make an exposure. Important nerve and vascular structures which cross the joint are identified and isolated if they lie within the operative field; otherwise they are retracted with the soft parts by being freed in a dissection which keeps close to the bone. Ligaments, scars, and callus which interfere with freedom of the bone ends are carefully cut away by sharp dissection and chisels. Attention is given to freeing the joint on all contacting surfaces and obtaining freedom of motion in all normal directions. About some joints tendons must be cut. They can be united, or left free if divided near their insertion. If reduction cannot be made without great strain and pressure on the soft parts, it is wiser to resect part of the bone ends; *one* bone is usually selected, and the cut-off end is fashioned to correspond with the original joint. Very few joints can be thus reduced after extensive operation and freedom of motion be hoped for without the additional use of interposing flaps of fat, fascia, or muscle. Consequently the complete operation really consists in arthrotomy plus arthroplasty and in some cases excision of bone.

After-treatment and Results.—Traumatic dislocation which is reduced soon after the luxation requires rest for the healing of capsular tears and absorption of intra- and periarticular effusions. Some dislocations are attended by great local infiltration. The greater the reaction, the longer the rest needed after reduction. Dislocations caused by direct violence which sustain great capsular damage as a rule demand a long period for regeneration of the lacerated tissues. When pain ceases in the joint and swelling subsides, active use can be started within the painless limit. Generally a simple sling or a light padded splint affords sufficient protection and immobilization for a week or ten days. It is best to avoid positions of the limb which will throw stress on the weakened and healing tear in the capsule. If joints are immobilized too long they become stiffened, and after dislocation the time for beginning movement must be selected in accordance with the joint involved and the amount of painful reaction. Light massage has an influence on the circulation in the periarticular structures and muscles, and should be employed for that purpose alone, not as a forcer of passive motions. Function after uncomplicated reduced dislocation usually becomes normal again.

Habitual and recurrent dislocations need a longer period of immobilization, generally in a permanent dressing for three or four weeks, with restriction of motion by a guarding splint or adhesive dressing for a period of one to six months thereafter. The after-treatment also depends on the character of the original method of treatment, whether operative or not. Failure to obtain permanent reduction frequently exists. (See the Specific Joints.)

The after-treatment of old dislocations reduced by extensive operation is a matter of considerable importance. If the joint is a superficial one like the elbow or knee, it is common to find sloughing of part of the skin which is under the greatest tension. This usually involves only the superficial surface, and every effort must be made to keep the gangrene dry. Stitches must not be removed from the skin early, even in the face of light infection. Alcohol dressings, care in handling, elevation, and anodynes for pain constitute the line of treatment. Most of all the surgeon and patient must not despair of a fair final result. If the edges of wounds slough, they must be kept clean and allowed to granulate, skin grafting following later. Passive movements must be persisted in from a time within a few days after operation, and active contraction of the muscles must be constantly encouraged. Final results take many months to culminate, and if failure results from the standpoint of mobility, the limb's contour and position are often greatly improved. When ankylosis threatens, the joint should be allowed to stiffen in a position which will promise the best functional use of the limb.

CHAPTER VIII.

FRACTURES OF THE SKULL.

The bone lesion in skull fractures is for the most part the least significant feature; the associated damage of the cranial contents is far more important. A split or depression of the skull in itself is of no great moment, and consequently the subject of fracture of the skull alone is a small one. The interrelation between the brain and its covering is so close, however, that we must study skull injuries largely from a physiological standpoint in regard to their disturbance of the central nervous system, and must understand the mechanism, signs, and symptoms of the bone injury in order to interpret the cerebral disturbances.

The adult skull is a rigid mass of bone nearly globular in shape. The vault affords an almost uniform bony continuity with closed sutures, but the base is punctured by many openings for nerves and vessels. The base is also buttressed and supported by ridges of heavy osseous tissue, and when a dried skull is held before a strong light one has little difficulty in picking out the thinner and weaker areas. These are located in the three fossæ, the anterior cerebral, the middle, and the cerebellar, which are the favorite site of cracks extending along the skull. Hilton has described also the strong points of the vault of the skull, which are furnished by buttresses. The principal one is an anteroposterior thickening of the bone extending from the glabella to the occipital protuberance, and there are besides two lateral ridges, one anterior, arising from the external angular process, passing upward through the frontal eminence to the anteroposterior buttress, and the other posterior, from the basilar processes through the parietal eminences to the midline above.

Adult bones vary in size and amount of cortical tissue, and nowhere is this better illustrated than in the skull with its two layers of compact bone and the soft cancellous diploë, which carries bloodvessels, lying between. Cranial bones are very thin in some adults and the diploë, a very meager space between the tables, while the child's undeveloped bones are much softer and withstand bursting pressure better on account of their greater elasticity. Roentgenograms have added much to our knowledge of skull injuries, as they have to all bone lesions, and diagnosis can be made with greater certainty by their help, particularly in question of the presence and extent of fractures at the base.

Accepting the bone lesion as a relatively secondary matter, we find a simple classification to consist in (1) Indented or punctured fractures. (2) Bursting or radiating fractures.

These two types may be combined, but they are in large measure distinctly separated and afford a convenient difference in mechanism and evidence of fracture.

Skull fractures may also be classified as open or closed, or, in accordance with the lines of fracture, as comminuted, depressed, linear, fissured, or with loss of substance. Clinically they are also often divided as fractures of the base and vault.

Indented or Punctured Fractures.—Indented or punctured fractures are caused by a body striking the skull with sufficient force to bend the bone toward the cranial cavity and expending its power quickly before the skull is altered in shape so as to cause lesions at a distant point. This situation may result in a fracture of either one or both tables of the vault and a carrying in toward, or into, the brain substance, of fragments of bone. The outer table may be bent in or indented and slightly depressed into the diploë without injury of the inner table, or the elasticity of the outer table may save it from a loss of continuity while the inner table is broken and depressed into the cranial cavity. This localized indentation of the vault arises from the causative forces overcoming the local resistance or elasticity in a small area. This elasticity is resolved into two components, one a tension resistance against force tending to pull the bone parts asunder, the other a pressure resistance against compression. It has been shown that the resistance against pressure is about one-third greater than the tensile strength (Rauber) a fact which would explain the circumstance that the outer table bends and may spring back into former shape unharmed, while the inner table gives way because of less tensile strength. It is exposed to force tending to pull apart its component particles, the same force driving together the particles of the outer table. Hence if the force has exhausted itself at the time the inner table breaks, the outer table remains unbroken, but if it acts beyond this point the outer table is also fractured. In this usual condition of fracture of both tables, the inner suffers damage over a wider area than the outer, and as the shock-absorbing diploë is necessary for this mechanism, we do not see this condition illustrated in the skulls of children and the old. With them the two tables are broken together and in about the same extent. Adults who are deficient in diploë, when subjected to fracture force sustain severe comminuted lesions. Gunshots which make a sudden sharp puncture and then proceed to penetrate the opposite side from within outward reverse the order of this mechanism (Fig. 36).

These punctured injuries are caused by small blunt or sharp objects striking the skull, as a pointed stick, a gunshot, or an umbrella ferrule driven into the vault or base, or by falls on a sharp edge of a stone which punches a hole in the bone. Small and sharp bodies puncture the bone, larger and blunter objects indent in a linear manner with an area of depression on one or both sides or drive in a large piece of the tables.

Bursting or Radiating Fractures.—Bursting or radiating fractures are caused by a solid body striking the vault with force, or to indirect

indentation of the bone. Should the tensile or cohesive strength of the bone be overcome at a distance from the application of force, the result is a bursting rupture along those axes parallel to the polar diameter which have been compressed to the breaking point. Indirect violence transmitted from the spine results in a bursting fracture of an irregular circular character at the skull base, and into the displaced area fissures or lines penetrate from the point of impact.

It is further observed and substantiated by von Bruno and von Wahls's experiments that because the base is the weaker hemisphere of the globular skull it makes little difference in which direction the polar diameter of the force extends, because the portion of the meridian passing through the base will give way first. Consequently different types of causative trauma, a blow on one side of the head, a squeeze of the whole skull, or a diffuse blow on the vertex may cause the same basal fractures. Most of these bursting fissures, found at autopsy or in the roentgenogram, tend to run in a transverse diameter, but they occasionally pass in a longitudinal direction. Excellent illustration of this is given by Homans,[1] who compares these skull fractures to the cracking of a pecan by force applied at each end. Radiating cracks appearing in the nutshell take a general direction from pole to pole in the long, meridian lines, but their exact course is determined by the weaker spots in the shell. Similarly in the skull, the cracks appear to take the direction of the causative force and pass toward the opposite pole, being influenced by the weaker spots of the thinner-walled fossæ. Felizet, in 1873,[2] reiterated this idea and asserted that the bursting fractures almost invariably ran out through these three fossæ, and that external evidence of damage to them was easy to explain. Walton[3] took this idea up again, and it is at this time the most widely accepted physical theory of these injuries.

Frequency.—Out of a total number of 11,302 fractures reviewed by the author, there were 1136 skull fractures. For the sake of simplicity, an average year (1914) may be taken. In this year there were 148 cases admitted to the Cook County Hospital, of which 71 died, 73 recovered to return to a more or less normal condition, and 4 were badly demented or suffered mental changes permanently as far as the records show. Many patients left the hospital within a week after injury, and no further information about them can be obtained. Analysis of the 148 cases of a typical year shows that 118 were basal fractures and 30 were strictly of the vault, 9 being specified as linear, and 9 as having depressed fragments of bone. Of the total number of 1136 skull fractures the mortality was nearly 50 per cent. In the time covered by this number, 8 years, there were performed 126 operations for elevation of fragments or for other decompression procedures, followed by death in 63 cases, exactly 50 per cent. Although the technic and possibly the selection of time and indications for operation have improved in these 8 years, it may be interesting to show

[1] Boston Med. and Surg. Jour., clxvii, No. 20, p. 685.
[2] Thèse de Paris. [3] Ann. of Surg., November, 1904.

that the postoperative mortality has varied little and at least has not lessened.

1907	number operations on skull fractures				21,	deaths	9
1908	"	"	"	"	23	"	13
1909	"	"	"	"	11	"	2
1910	"	"	"	"	11	"	6
1911	"	"	"	"	17	"	11
1912	"	"	"	"	16	"	7
1913	"	"	"	"	14	"	7
1914	"	"	"	"	13	"	8

Pathology.—1. *Punctured Fractures.*—Small indentations of the tables of the skull, either one or both, may result in no damage to the brain beneath. If both tables are depressed by a blunt object, the dura may remain intact, and there will be little pressure on the brain

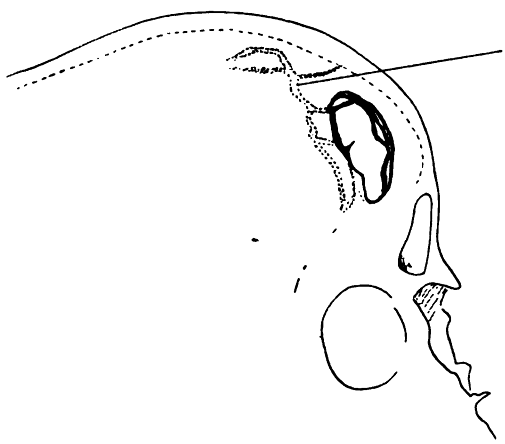


FIG. 37.—Punctured fracture of the frontal region. The outer table has been depressed. The inner table has also been depressed slightly and is extensively comminuted.

(Figs. 37 and 38). Hemorrhage may occur from the superficial tissues, which are usually lacerated, or from the diploë, and if vessels of the dura are opened they may also contribute to a bloody discharge. Usually the inner table is more comminuted and exhibits a larger fractured area than the outer table. The inner table alone may be fractured and depressed without apparent damage of the outer table, but these cases are very rare. Concussion of the brain and death are not frequent in this type without other injuries. Gunshot and umbrella punctures usually penetrate the brain substance and have complication from immediate injury to the central nervous system, or from later consequences such as hemorrhage, meningitis, and abscess. This is especially true when the accessory sinuses of the face or the eye and nose are opened into. Ross[1] reported a case of punctured wound

[1] Ann. of Surg., xlvii, 108.

in the right orbit which resulted in a cerebral abscess involving the whole right temporosphenoidal lobe. The greater wing of the sphenoid

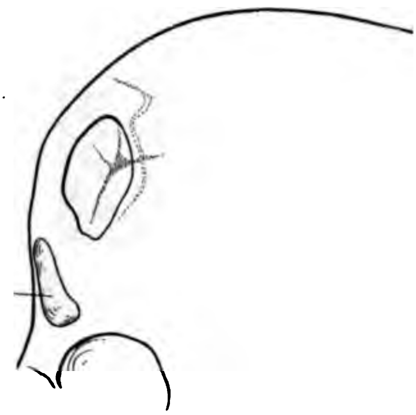


Fig. 38.—Operative repair of the preceding. Bone fragment of the outer table removed. The depressed comminuted inner table elevated a normal level. Dura not injured. Recovery.

was found fractured, and the floor of the orbit was opened into the roof of the antrum of Highmore, showing the line of the infection from the nose *via* the antrum to the middle cerebral fossa. The punctured

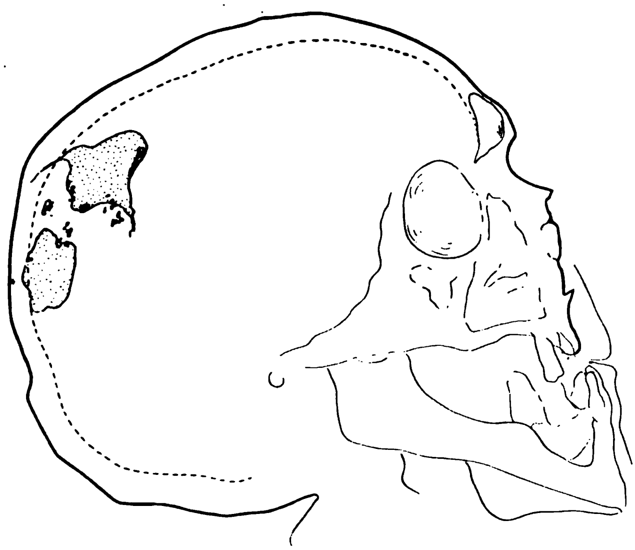


Fig. 39.—Open fracture of skull from bullet wound.

fractures due to high-velocity bullets are fatal for the most part either on account of immediate brain injury, or later infection and hemor-

rhage. Wharton[1] collected a series of 316 cases of foreign bodies in the brain. Some of these were caused by swords and bayonets, others by ferrules of canes and umbrellas; five were penetrations of the sphenoid, and 18 were wounds of the orbit.[2]

Friedrich[3] kept full record on 43 cases of firearm wounds of the skull and brain and had very high percentage of recoveries. He did not trephine in all cases unless there was evidence of cerebral symptoms. The author has seen 2 cases of suicidal gunshot punctures which severed both of the nerves and caused complete blindness, but no other symptoms. Gunshots of the skull and brain studied from their physiological standpoint have confirmed many of the brain localizations worked out by experimental physiology. Rothmann[4] has reported some interesting cases regarding the visual centres in the occipital lobe and various motor aphasias which were cured by removal of the bullets from areas physiologically anticipated.

Horsley, in 1894, experimented on the explosive effect of high-velocity bullets in connection with gunshot wounds of the head.[5] He used modelling clay which contained some water, and after the explosive force had deformed the mass he filled the cavities with plaster of Paris to preserve the effect of the shot. The conclusions reached were that the explosive effect of the bullet was directly proportional to the sectional area of the bullet, its velocity, and the amount of water in the substance through which it passed, the forces of disruption acting at a right angle to the axis of the bullet's flight. The greatest amount of damage was done by the bullet when at its highest velocity and surrounded by the largest mass of wet tissue.

In animals and in the skull of man these conditions are influenced by the fact that the water-holding material, *i. e.*, brain, is surrounded by a semielastic bone envelope. The larger wound of exit of gunshots in the human body is caused by the driving out, in penetration shots, of all fragments of bone or other tissues to which the velocity of the bullet has been communicated.

Modern bullets possess two movements, the forces of which have a bearing on the injury. These are the forward progressive penetration and the rotary spin arising from the rifling of the gun barrel. Of these two the most important is the rotation of the bullet, the effect of which Horseley observed was still visible on the plaster casts of his experiments up to the time when the bullet ceased to penetrate. He believes that the disruption of tissues in wet clay must be attributed

[1] Philadelphia Med. Times, July 19, 1913.

[2] Cases of punctured fractures *not* followed by abscess or infection: Brown and Birch, Philadelphia County Med. Soc., 1889, x, 395; Ferguson, New York Med. Jour., 1896, lxiv, 360; Semonnier, Bull. Soc. Méd. et Chir. de la Drone, 1904; Fisher, Deut. Ztschr. f. Chir., 1882 3, xviii, 411; Kennedy, Glasgow Med. Jour., 1905, lxiii, 394. Cases followed by abscess: Felty, Med. News, Philadelphia, 1894, lxv, 710; Rehns, Aerztl. Int. Blatt., Munich, 1881, xxviii, 45; Prideau, Lancet, London, 1886, ii, 846.

[3] Beitr. z. klin. Chir. Tübingen, xci, No. 2.

[4] Berl. klin. Wchnschr., lii, No. 13.

[5] Proc. Roy. Instit. Great Britain, 1895, xiv, 228; British Med. Jour., February 20, 1915, No. 2825.

for the most part to the water, because particles are thrown off at right angles to the axis of the bullet's flight. In a number of the *Lancet* (London) for 1915, two cases of gunshots of the head reported by a correspondent confirm these ideas. In one case a shot of maximum velocity entered the head just in front of the ear, and made exit at a point exactly opposite. The bullet track was straight, and although the wound was really a wound of the face, it proved instantly fatal. When the skull was opened, it was found that death was probably caused by the condition of the under surfaces of the frontal lobes of the brain, which had been reduced to a structureless jelly by the lines of force emanating from the rapidly traveling bullet. A second case had occurred after the bullet had travelled 2000 yards and had a small residual momentum. This bullet had entered the forehead, traversed the head, struck the occipital bone on the inside, and rebounded over the original track to a place near the point of entrance. There was no general bruising of the tissues about the track of the bullet.

The sectional area and not the shape of the point of the bullet is also of importance to the character of the result of the shot. Soft-nosed or dumdum bullets deform easily, and their expansion increases their sectional area greatly, but modern hard-nosed bullets make the same wound whether of blunt or long nose. Horsley also showed that turning over of the bullet was common, but that the bullet turned only *once*, near the middle of its course through the clay, at a point when its progression velocity was greatly reduced and the advance of the bullet became more sensitive to obstructions. The first effect of these obstructions is felt by the lighter tip of the bullet. The bullet's heavier base swings around, converting the primary tubular wound into a triangular cleft, the base being formed by the broad base of the bullet and the apex by the point. The turning over does not produce as much harm as the high velocity and the continuance of the rotary spin.

Punctured fractures may result in the formation of meningocele from hemorrhage, or this may result from irritative secretion following trauma. Hayner[1] cited a case of ten years' standing in which a large cyst, which gave but few eye and headache symptoms, compressed the occipital lobe. Its outer wall was formed by the pericranium.

2. *Bursting Fractures.*—These frequently have no scalp lacerations but may show a swelling or ecchymotic area on the head. Lines of radiating fracture pass across the vault, usually toward a point opposite the application of the trauma; or radiate down into the fossæ at the base, across the middle line, and sometimes into the foramen magnum, the orbits, or through the petrous portion of the temporal bone into the middle ear, rupturing the tympanic membrane. The cracks in the bones are of little interest in themselves, but are very important in their relation to the division of meningeal vessels which

[1] Ann. of Surg., liii, 269.

are partly imbedded in the bone and the hemorrhage from which may be inaccessible. The brain may be jarred and concussion follow; blows

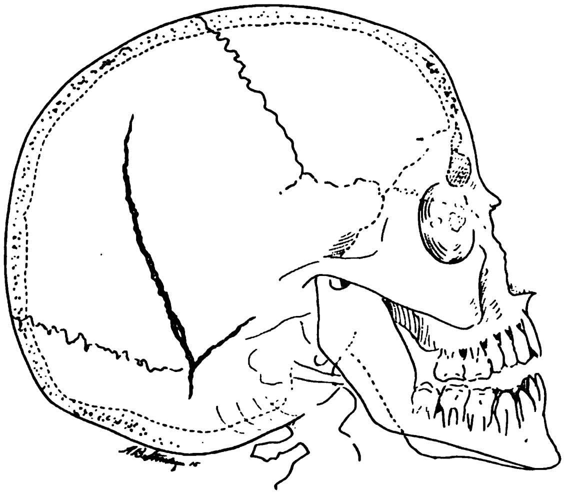


FIG. 40.—Vertical linear fracture without a scalp wound. As far as the roentgenogram shows this does not extend into the base.

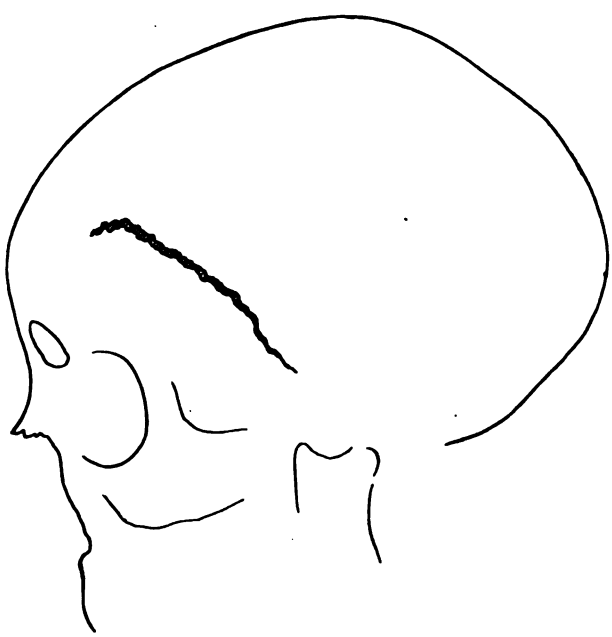


FIG. 41.—Oblique linear fracture in the temporal region. This is the type which involves the meningeal artery.

severe enough to cause concussion do not always break the skull. The brain in fracture may be shaken and lacerated for a distance of

several centimeters into its substance, and cortical hemorrhage may occur, especially hemorrhage into the pia mater, which gives a bloody

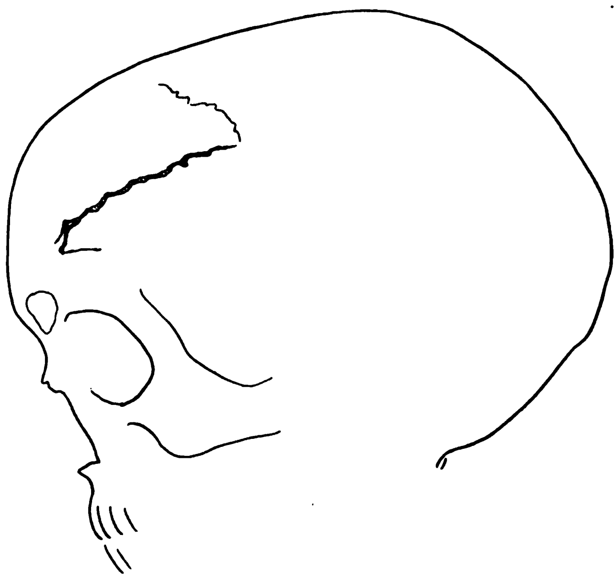


Fig. 42.—Linear fracture originating in the frontal region and passing backward in the longitudinal axis of the skull.

Fig. 43.—Bursting fracture in a child's skull passing clear around the vault and giving symptoms of basal involvement.

cerebrospinal fluid. On account of the rapid circulation of this fluid and its absorption by the arachnoidal villi into the venous sinuses,[1]

[1] Weed, Jour. Med. Research, 1914, xxxi, 51.

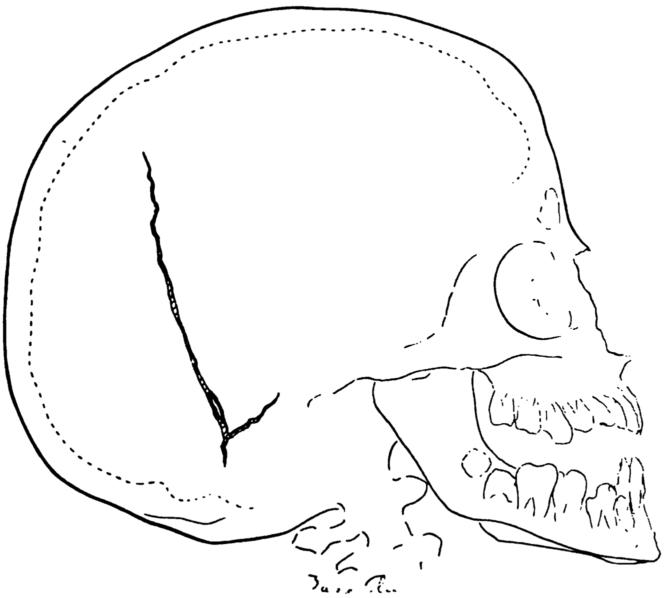


FIG. 44.—V-shaped fissure, one leg running into the mastoid and middle fossa. Hemorrhage from ear.

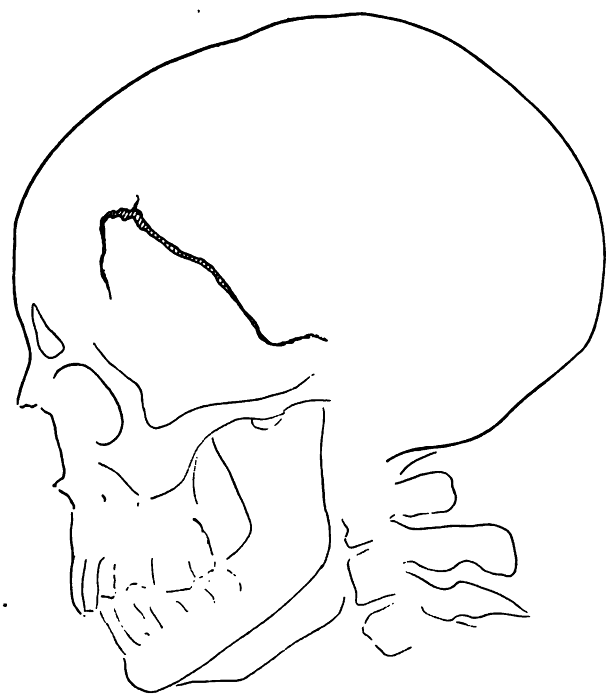


FIG. 45.—Irregular fissure involving orbit with hemorrhage.

the finding of bloody cerebrospinal fluid by lumbar puncture gives immediate evidence of cortical hemorrhage. Cerebral edema causing

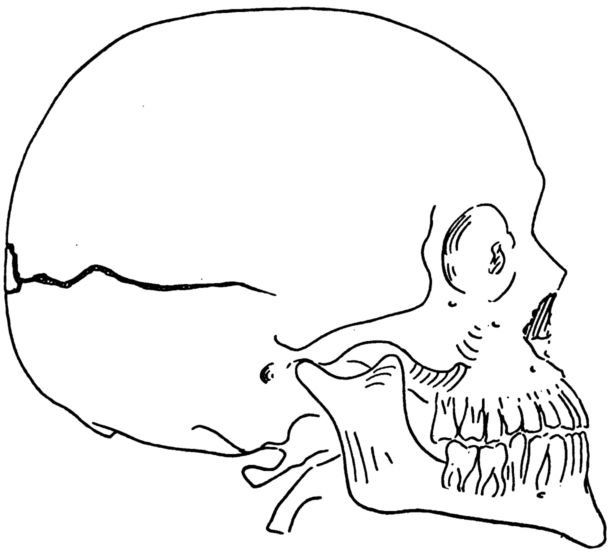


Fig. 46.—Fissure in long axis of the skull involving the occipital bone and lobe of the brain.

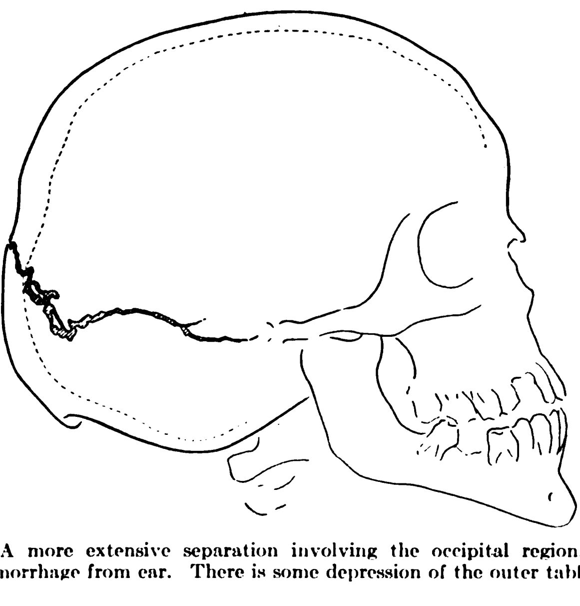


Fig. 47.—A more extensive separation involving the occipital region. No scalp wound. Hemorrhage from ear. There is some depression of the outer table at the site of fracture.

increased intracranial pressure may follow within a few hours, or after several days.

The brain is also subject to a compression from meningeal or dural hemorrhage as a *direct result* of the bending skull fracture. Because many of these fractures pass through the temporal fossa, the vessels which groove the bone are likely to be torn, and hemorrhage from them occurs *outside* the dura, the force of arterial pressure dissecting the meninges away from the inside of the skull and causing a hematoma formation. (See Symptoms of Middle Meningeal Hemorrhage.) With increasing cerebral pressure symptoms and a normal cerebrospinal fluid, extradural hemorrhage is suspected, although both intra- and extradural forms may be present simultaneously.

Hemorrhage from the ear, nose, pharynx and into the orbits, pointing beneath conjunctivæ and lids, or ecchymoses and edema about the mastoid, are found, depending on whether the cracks are in the temporal bone, the middle or anterior fossæ, the orbital wall, or the inferior occipital fossæ. Deafness may follow bursting fracture; the author has seen one case Lüken[1] reports an instance in a man who fell twenty feet and landed on his head, the mechanism probably being pressure of the axis transmitting the body weight against the occipital bone causing a bursting fracture at the base of the cranium forward through the jugular and carotid foramen into the sella turcica. The glossopharyngeal, vagus, and accessory spinal nerves lying in the jugular foramen were exposed to injury—the accessorius and vagus were damaged with the resulting deafness. Deafness might also follow hemorrhage into the inner ear and semicircular canals, but this is accompanied by vertigo and other pronounced symptoms and is rare. Blindness without visible injury of the eye-grounds has also been noted. Newmark[2] reports three cases following the trauma of bursting fracture. The partial loss of vision was not recognized by the patients and was caused in part by bilateral occipital hemorrhage or injury to the occipital lobes. The vision was greatly circumscribed and central. One case of a four-year-old boy gave a long, slow recovery. Severe diabetes after skull fracture with death in ten months was reported by v. Noorden.[3] Churchman[4] has recorded a case of basal skull fracture with motor aphasia and recovery after operation. He found a superficial laceration of the paracentral gyrus of the left frontal lobe in the Broca area. The patient made a complete recovery from his aphasia but became slow mentally. In May, 1915, I had two cases of aphasia following skull fracture in young boys. The first case was in a lad of fourteen years, who was injured by an automobile. He had an open fracture of the left parietal region and undoubtedly had extension cracks involving the basal fossæ. He was not unconscious and had no focal symptoms nor paralysis. There was some twitching of the right side of the face, but no eye symptoms. His only trouble seemed to be an inability to talk. He could read printed words, could

[1] Arch. f. klin. Chir., civ, No. 4, p. 1000.
[2] Jour. Ophth. and Oto-Laryngol., viii, No. 5, p. 143.
[3] Jour. Am. Med. Assn., October 16, 1909, liii, 1303.
[4] Ibid., lxiv, No. 15, p. 1233.

understand everything said to him, and answered by head movements. His tongue showed no paralysis. Decompression was performed, and a depressed area of bone just posterior to the Rolandic fissure was elevated. The dura was opened and the cortical surface was explored well forward into the supposed speech-centre area. Some cortical edema was present but no surface laceration. A large fissure extended backward toward the occipital bone, from which direction subdural hemorrhage arose. A good-sized area of bone was removed, and gutta-percha drainage was inserted. Convalescence was satisfactory. The scalp healed promptly after several days' discharge of cerebrospinal fluid and blood. After four or five days his power of speech gradually returned, and within two weeks he could talk normally. There was no disturbance of gait or equilibrium.

The second case was at Provident Hospital in a seven-year-old boy who had been struck on the left parietal and frontal bones by a baseball bat. This was also an open fracture with depression in the temporal fossa of a circular fragment about the size of a silver dollar. The lad was conscious and had no focal symptoms except slight facial paralysis of the right side. He was unable to talk, but understood questions and could put out his tongue. The fragment was raised and the dura was found to be lacerated, as was also the cortical surface in the neighborhood of the paracentral gyrus. Four days after the operation he began to talk and went on to a perfect recovery, going home on the twelfth day. Whether these aphasias arise from concussion injury of the supposed speech centre in the frontal lobe or from injury of the occipital lobe is not positively known. The conclusion of much experimental and clinical observation favors the theory of injury to the occipital lobes, and the identity of a definite speech centre is questioned. Other pathological changes involve degeneration of the cranial nerves, especially the optic, acute and subacute parenchymatous inflammation of the cerebral cortex which may terminate in abscess or sclerosis. Secondary and delayed pathological changes include cerebral softening, sclerosis, and abscess.

Symptoms.—(1) *Punctured Fracture.*—The symptoms, as indicated in the pathology, group themselves around the bone injury and the brain damage. A punctured wound of the skull will nearly always be accompanied by an external wound of the scalp or head tissues from which there is hemorrhage, discharge of cerebrospinal fluid, or protrusion of brain substance. Injury to the vault with a scalp wound means an open fracture. Through the scalp opening the hole or depression of the skull tables can be seen or felt and the existence of fracture verified. Punctures of the base or through the face are more difficult to determine, and measurements of the wound depth with a probe, or roentgenograms of the head with a probe lying in the wound, will be of invaluable aid. Bullets and foreign bodies can be located accurately by stereoscopic pictures. The escape of cerebro-

spinal fluid or pieces of brain tissue is also proof of penetration into the brain. Delayed symptoms are a sudden or gradual rise in temperature a few days after injury when the previous course has been afebrile, or a normal pulse rate which falls to 50 or lower, both indicating infection and abscess. Likewise disturbances in consciousness, irritability, or increasing somnolence are signs of infection, while headache alone is not sufficient. Friedrich advises the importance of taking the patient's temperature between midnight and 2 A.M. to obtain the earliest evidence of a rise in a case which is afebrile at all other hours of the day.

The venous sinuses may be opened directly by a punctured wound and give a copious hemorrhage of venous blood which is difficult to control. Cerebral concussion and other brain symptoms which depend on the disturbance of the central nervous system will be described under Bursting Fracture.

2. *Bursting Fracture.*—This may accompany or be an extension of punctured fractures. Bursting linear cracks may be limited to the vault or pass into the base as described, and symptoms may be absent, the roentgenogram confirming the presence of the cracks. A scalp wound or a hematoma beneath the scalp is not necessary, and in many bursting fractures which involve the base these are absent. Concussion of the brain or loss of consciousness generally accompanies these head injuries, although this happens without bone injury. It is the easiest sign to recognize, and *changes in consciousness* without complete loss, are important. The patient may be unusually quick and bright mentally and answer all questions freely and correctly, and in a few hours not know that he has ever seen the surgeon nor made replies.

Damage to the medulla is a more acute type of this concussion, and the vital function most easily influenced is respiration, with vagus control of the heart and interference with the vasomotor centres and a lowering of blood-pressure following in order. According to the severity of the concussion, we may find first a change or loss of consciousness, usually transient and unaccompanied by other signs. Secondly, we find a loss of consciousness with respiratory changes, usually a rapidity or Cheyne-Stokes type, and a rise in blood-pressure and a slow, full pulse, which endeavors to compensate and carry blood to the medulla. A more severe stage is characterized by loss of consciousness, a rapid, weak pulse, and irregular respiration, which, if not followed by a compensatory rise in blood-pressure, leads to early death.

When the jarring *is greater*, the brain may be shaken and badly bruised with a laceration of its substance, without demonstrable fracture. These injuries result in hemorrhage which is shown by lumbar puncture. If the spinal fluid is blood-tinged and under pressure, so that it runs out of the needle at a rate faster than the normal dropping, increased pressure and hemorrhage from cerebral laceration

are positive. This is an immediate sign of great value. Very rarely differentiation from intraventricular hemorrhage has to be made.

LeConte and Bissell,[1] in 200 autopsies on deaths in coma at the Cook County Hospital, found that the average age of cases dying from cerebral hemorrhage was over fifty, while the average age of fatal cases of skull fracture was at least ten years less. It is also interesting to note in studying the clinical histories of these cases that the skull fractures gave great variation in the blood-pressure, a relatively low average being found, whereas the cerebral hemorrhage cases were uniformly high and averaged nearly 190. The most important and the earliest sign which can be obtained, and that while the patient is unconscious, is the presence of blood in the spinal fluid. In old cases, with healing or healed scalp wound and unconsciousness or sudden rises in temperature, the finding of pus or a spinal fluid with great excess of leukocytes is also uniform. Spinal puncture in head injuries and comas should become a routine method of examination.

Meningeal hemorrhage occurs most often when the vessels grooving the bone are ruptured. Usually this occurs in cracks across the temporal fossa and the middle meningeal is the vessel involved. A primary unconsciousness due to the concussion is followed by a period of consciousness of varying length, succeeded by another lapse into unconsciousness with evidence of increasing intracranial pressure. The secondary unconsciousness is caused by the gradual development of the extradural blood mass, which exerts enough pressure to encroach on the motor centres, or inhibit sufficient blood supply to the brain, a cerebral anemia following. If other less important meningeal vessels are torn, hemorrhage is slower, and the symptoms are those of gradually failing consciousness and paralysis of slow onset appearing late after the brain is recovering from other injury. The extradural hemorrhage alone does not give a bloody spinal fluid as mentioned in the pathology. If the symptoms of the first shock do not improve inside of a few hours, if the depression of the medullary centres evidenced by rapid pulse and respiration is not overcome, or if unconsciousness deepens even without definite focal symptoms or evidence of bone damage, the injury is undoubtedly to be classed as severe. When the patient is to survive, there is a reaction, and a compensatory slow pulse and high blood-pressure develop; but the injury may be so severe that this never occurs.

A low degree of fever in the first few hours is common, and a rapidly rising temperature reaching from 105° to 108° is indicative of derangement of the medullary centre, and approaching death. The leukocyte count generally does not vary in the first twelve hours; after that it rises as high as fifteen to twenty thousand from effect of hemorrhage. Alcoholics do not react normally; they usually remain unconscious with a low blood-pressure and weak cardiac action.

Hemorrhage is the one sure indication of bursting fracture involving

[1] Jour. Am. Med. Assn., xiv, No. 3, p. 189.

FIG. 48.—Irregular planes of bursting fracture passing from the vertex to both the orbit and the ear, producing subconjunctival and ear hemorrhage.

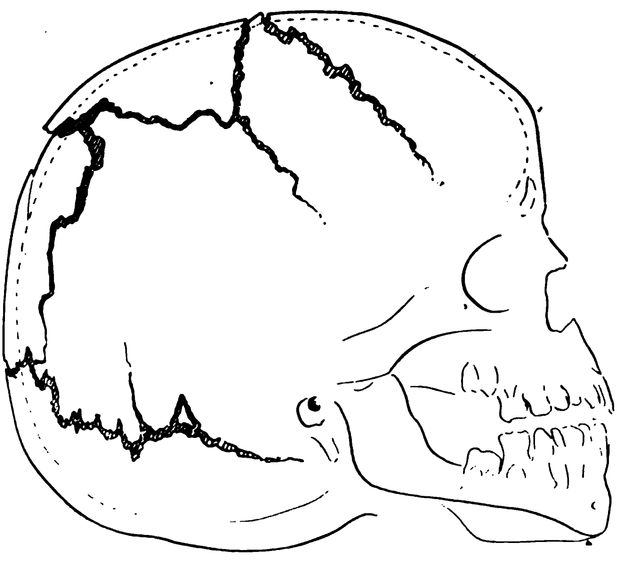


FIG. 49.—A severe crushing of the skull with multiple planes of fractures and displacement of both tables. Recovery. This case practically is a decompression within itself.

the base. From the sources in the fossæ described, it becomes visible upon or beneath the outside surface of the head. It may be manifested

Fig. 50.—Child's skull fractured by fall from a height. There is wide separation of fragments.

Fig. 51.—Severe bursting fracture with comminution.

beneath the conjunctivæ, from the nose, ears, mouth, or into the subcutaneous tissues around the eyes or the mastoid regions. Phelps[1]

[1] Ann. of Surg., xlix, 449.

analyzed 1000 cases of head injury and obtained the following statistics of hemorrhage in 405 basal fractures:

		Recovered.	Died.	Total.	Necropsies.
Hemorrhage from ear		166	119	285	69
Hemorrhage from nose and mouth		39	51	90	32
Subconjunctival hemorrhage		9	8	17	7
Subcutaneous hemorrhage	Mastoid	3	6	13	9
	Cervical	0	3		
	Orbital	0	1		

Ransohoff found hemorrhage from cranial openings beneath the conjunctiva and under the scalp in 163 out of 190 cases, hemorrhage from one ear in 60 cases, and from both ears in 8 cases.

FIG. 52.—Recent bursting fracture with punctures. Note the hemorrhage from the left ear proving the presence of a crack in the middle fossa. A fatal termination.

The author's observation of cases shows a larger percentage of subcutaneous hemorrhage about the orbit and a smaller proportion of ear hemorrhage. Immediate subconjunctival or orbital hemorrhage is caused by contusion at the time of injury; that caused by fracture involving the orbital wall does not show for several hours and is often delayed for one or two days. It passes through the colors and stages of absorption and in ten or twelve days has largely disappeared, the subconjunctival persisting much longer. Mouth and nose hemorrhage with no local lesion on the face, particularly nasal hemorrhage after twenty-four hours, indicates fracture through the anterior or middle fossa. These give a higher mortality than ear hemorrhage, probably

on account of greater trauma and liability to infection from the septic nares. A hematemesis after head injuries, if tongue and other local injuries are absent, suggests fracture into the pharynx or nose. Subcutaneous hemorrhage around the mastoid is caused by a splitting of the inferior occipital fossa, although a temporal hematoma might gravitate there. Edema from disturbed return circulation may also be a sign about the mastoid.

Hemorrhage from the ear caused by rupture of the drum, following a bursting crack, is common, and the auditory canals should be carefully inspected for its presence. When this symptom is present in closed bursting fracture, lumbar puncture should be made to determine the presence or absence of cortical and pial hemorrhage.

Other symptoms of basal fracture are rare. Serous discharges from extravasated blood within the skull, cerebrospinal fluid, the discharge of middle-ear inflammation or a serous arachnitis, may come from the scalp, ear, or nose. Phelps found this in 26 cases, 9 of which were fatal, 7 from the ear and 1 each from the vault and nose. The cranial nerves may be involved either by pressure or injury in the peripheral portions or origins. Particularly the optic nerve is subject to an edema developing after a few hours of increased brain pressure, giving a choked disk on ophthalmoscopic examination, or the third, fourth and sixth nerves may be implicated. Vaughan, night warden at the Cook County Hospital, investigated the ophthalmoscopic findings of head injuries for a period of two years. In that time he found but 2 cases which showed even early symptoms of choked disk, and they were not cases of immediate injury. He is of the opinion that small retinal hemorrhages are seen early and are evidence of cranial damage. Strabismus, irregular and unequal pupils, failure to react to light, may be found. Unilateral dilatation is the common finding, Ransohoff found it 45 times in 127 cases, 11 of which died. The facial may also be involved so that a hemiparesis of the face muscles is present with a twisting of the mouth toward the unparalyzed side from unbalanced muscular action, and a blowing out of the paralyzed cheek in respiration. Irritative twitchings of the face are also commonly present. Injuries of other nerves governing the tongue action and swallowing may be present.

Extrusion of brain substance is sometimes found in a scalp wound or into the nose and pharynx. Brewer[1] reported a bursting fracture in a nine-months-old girl. Where the scalp was opened a three-inch fissure across the parietal bone was found, joined by another anteriorly. The skull was depressed at this line of fracture, and there was a sausage-shaped mass of necrotic dura and cortex two and a half inches long, by three-quarters of an inch in diameter, which had probably been pinched out between the bone edges as the crack opened. Paralysis and convulsions are primary or secondary, caused by trauma or hemorrhage and increased intracranial pressure. Late convulsions,

[1] Ann. of Surg., xlviii, 125.

general and not epileptic in character, but due to delayed or recurring hemorrhage, may appear. Spiller[1] reports an instance in a man of fifty-nine, who was unconscious for fifteen minutes following a skull injury, but who gave no evidence of paralysis or hemorrhage. He died of a bulbar paralysis after seven weeks, and the presence of hemorrhage in the bulb was verified by autopsy.

Loss or change in muscular tone is present in some cases and is a valuable aid in diagnosis when complete unconsciousness exists. If a limb on one side is flaccid when raised and dropped, while one on the other has some muscle tone, the presence of cerebral mischief on the side governing the toneless muscles is indicated. Relaxed sphincters with involuntary actions of the bladder and rectum are found in instances of severe concussion. These symptoms disappear as consciousness returns or persist if death is imminent.

The findings obtained through ascertaining of the blood-pressure are very helpful in determination of prognosis and treatment. An average blood-pressure for the patient must be kept in mind, taking age, condition of kidneys, and evidence of arteriosclerosis into consideration. A fast pulse and respiration with a low blood-pressure are unfavorable signs; the high pressure and slow pulse with a *gradual rise* when recorded every few hours, are first-hand indication of the fight the individual is putting up to supply blood to his brain, and call for external help if accompanied by bloody spinal fluid, focal symptoms of pressure, or continued unconsciousness. The use of the blood-pressure apparatus should be as frequent and as carefully recorded as the thermometer findings.

The use of the roentgenogram must also be recalled in the diagnosing of basal cracks and in the differentiation of comas. When the patient's condition permits, his head should be subjected to Roentgen-picture taking. This procedure helps rule out cases of concussion and also confirms bursting fractures through the base. Luckett and Stewart[2] advise the exposure of the head to the rays with a minimum amount of disturbance and movement, although the head should be fixed absolutely and the respiratory movements must not disturb it. A hypodermic injection of morphine may be needed for this purpose. For obtaining a view of the frontal bone the patient may be turned on his abdomen, or the tube may be placed beneath the head. If the occiput is to be shown the chin must be sharply flexed. The grooves for bloodvessels on the inner table are sometimes mistaken for cracks of fracture. The fracture lines are light and sharp cut and have a varying width.

Progress and Prognosis.—1. Puncture fractures with little or no depression of bone and no concussion usually promptly return to normal unless infection occurs in the scalp and bone. This infection may lead to late meningitis or to cerebral abscess by extension. If concussion has been present, recovery from it is generally followed

[1] Univ. Penn. Bull., xvi, 13. [2] Am. Jour. of Surg., xxviii, No. 1, p. 40.

by an uninterrupted convalescence, with rare secondary complication mentioned under Pathology. If puncture is uncomplicated, if fragments demand elevation and other operative procedures, the prognosis is good if there is no foreign body buried within the brain and no infection develops.

2. Bursting fractures, especially those of the base, yield an average mortality of 50 per cent. The prognosis is largely indicated by the *depth* of the mental disturbance and the length of the unconsciousness. This is so well recognized that of the 1138 cases reviewed in this series only 126 were operated on, because the symptoms of severe brain injury and the futility of adding operative shock were appreciated. The value of immediate decompression in the cases struggling to establish a compensatory equilibrium within the brain was not appreciated. A large percentage die within the first twenty-four

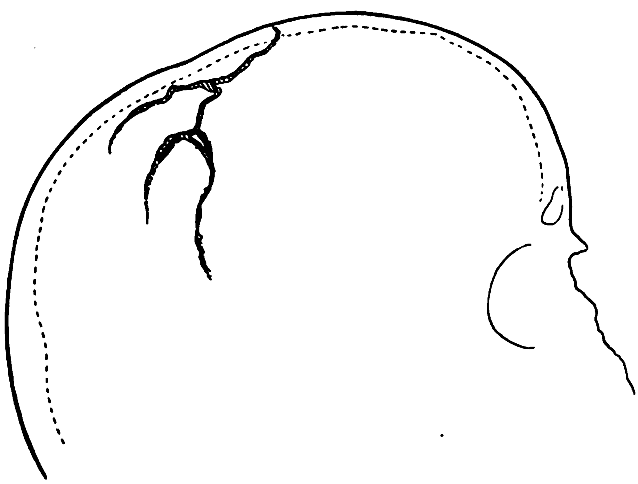


Fig. 53.—A peculiar type of bursting fracture known as the trident fracture. Note the 3-prong or tooth-like projections of the plane of fracture.

hours. Ransohoff[1] reviewed the prognosis based on 190 cases in ten years' experience and found a general mortality of 63 per cent., only 15 per cent. dying after the second day. The deeper the coma and unconsciousness, the poorer the prognosis; the more stertorous the breathing, the greater the indication of deep cerebral concussion and hemorrhage. Patients with coma lasting several days have recovered. Ransohoff cites one lasting six days. Coma developing late has an important bearing on prognosis, inasmuch as it indicates beginning infection, cerebral edema, or recurrent hemorrhage, and lessens the chance of recovery.

Crandon and Wilson,[2] in the records of the Boston City Hospital collected 530 cases with a mortality of 44 per cent. Fifty-nine were

[1] Ann. of Surg., li, 796. [2] Ibid., xliv, 823.

operated upon with a mortality of 53 per cent. Kantorowicz,[1] utilizing the Charité records from 1902–7, found 73 cases of basilar fracture with 25 deaths.

Other authors, as Schwarz,[2] reports 38 cases from Kiel with 14 deaths: Wanker,[3] 66 cases with a mortality of 28 per cent., and Frazier[4] found a mortality of 59 per cent. at the Philadelphia Episcopal Hospital.

The question of the development of epilepsy following skull fracture and brain injury is a large one and need not be entered into in detail here. Elsberg[5] makes the statement that one-third of all skull fractures develop general epilepsy or the Jacksonian type at any period from one to many years after the injury, and that unoperated cases are not more liable to have this sequence than cases operated on. The question of undisputed diagnosis of traumatic epilepsy will help determine this matter, and no figures will be authoritative until a large number of head injuries which are checked by roentgenogram can be traced for years from the standpoint of subsequent epileptic seizures. We do know at this time that but few cases obtain permanent relief from operation whether adhesions to the dura and cortex are found and divided, or an area of the cortex is sliced off, or whether fat and fascia flaps cover the supposedly irritated area and bone is replaced as bone hash or an osteoplastic flap, or the space left devoid of that covering. It is also right to affirm that when depressed bone fragments and clots are left epilepsy can be expected.

Treatment.—Treatment of skull fractures divides itself sharply along the line of the pathology, and it is not infrequently true that with a relatively mild bone injury, the damage to the brain and vital centres is so great that death is certain.

General care and treatment for head injuries consists in preserving the patient from further shock which may result from rough handling, exposure or hemorrhage. If unconsciousness is of moderate type and the concussion of the brain is the most important feature, with symptoms of rapid, feeble pulse, low blood-pressure and loss of vascular tone, vomiting, shallow respiration, and subnormal temperature, the indication is to apply external heat, diffusible stimulants such as strychnine or enemata, and give perfect quiet and rest. If transportation to a hospital or some distant point is necessary, a hypodermic injection of morphine is indicated. The concussion must be overcome, as it may mask other and more serious symptoms which cannot be ascertained in its presence. It is also advisable to obtain as clear an account of the accident as can be given by witnesses, and careful notation should be made of the condition of the pupils and the eyegrounds if possible, the presence or absence of hemorrhage from the

[1] Thesis zur Prognose d. Schädel Basis Brüche, Leipzig, 1908.
[2] Schädel Basis Brüche, Diss., Leipzig, 1903.
[3] Disser. Goettingen, 1900.
[4] Jour. Am. Med. Assn., 1909, lii, 885.
[5] Am. Jour. of Surg., xxviii, 38.

ears, eyes, nose, throat, lacerations of the tongue, and vomited blood. The scalp should be carefully inspected for contusions or the slightest clue of the point of injury in case there is no scalp wound, as a small finding may be of great assistance in determining subsequent treatment.

Concussion and scalp wounds indicate close scrutiny. Because the scalp and pericranium are closely joined together, and no prolongation of the fibrous tissues are sent into the bones of the vault, the scalp may be widely torn or avulsed without skull injury. On the other hand, a small scalp wound which shows in its depth nothing in the nature of bone damage may conceal a depression nearby, or bursting cracks taking origin just outside of its range. False security and diagnosis will follow superficial examination of such a scalp injury, and it is good surgery to investigate each wound, enlarging it at the ends and cutting down to the bone if there is the slightest suspicion of fracture.

Bursting fractures with evidence of hemorrhage at the base and with or without concussion or scalp wound are treated in accordance with the general principles. If the ears are bleeding, the canal is wiped out with a bichloride sponge and very lightly covered with a similar dressing. It is impossible to sterilize the nares in any degree. If the eyes later become swollen and edematous and some conjunctival discharge develops, mild antiseptic irrigation and sterile vaseline on the lids should be used. The patient is put at rest in a darkened room and an ice-cap is applied to the head. Attempt is made to determine which fossa is involved and whether the free interval of consciousness of middle meningeal hemorrhage occurs. If the sphincters have not been relaxed by the concussion a cathartic may be given, if the patient can swallow, and the bladder must be watched for overdistention.

Further treatment is symptomatic until consciousness is regained and focal symptoms manifest themselves or until unconsciousness or delirium persist and a rising blood-pressure and other evidence of increased intracranial pressure is observed. Lumbar puncture for diagnostic purposes often proves of therapeutic value, and if increased intraspinal pressure is found and some relief obtained by drawing off the fluid, the procedure should be repeated up to four or five times within twenty-four hours. Rinderspacher has called attention to the value of the findings in lumbar puncture,[1] and the importance of determining the pressure and microscopical examination of the cerebrospinal fluid immediately after head injury from a medicolegal standpoint. An increased pressure denotes a meningeal irritation or chronic serous meningitis, or an anatomical lesion within the skull, especially if accompanied by blood. Normal pressure does not disprove a cranial lesion, but if an increased pressure is found after accident, and later this subsides, the subsidence indicates that the increase had not kept up an irritating meningeal effect. Neurasthenical conditions do not effect the pressure.

[1] Fortschr. d. Med., 1914, xxxii, 405.

The advisability of giving hexamethylenamine as a prophylactic against meningeal infection from bursting cracks at the base, is disputed, and it is difficult to draw satisfactory conclusions. Experimentally it has been determined that the formaldehyde gas is not given off unless the medium in which the hexamethylenamine is excreted has an acid reaction. If the patient can swallow it does not seem to do harm, and it may have a helpful effect.

Operative treatment is primarily indicated in some cases. It is not necessary in those cases of mild concussion with no focal or increased intracranial pressure symptoms which seem certain of recovery. Likewise it is not necessary in the severer cases with great shock, fast pulse, deep unconsciousness and comminution of the skull with apparent irretrievable damage to the brain. These die in a few hours, or, if they do survive, the brain is hopelessly ruined. Treatment for them is care of the shock and a suitable aseptic dressing on the head.

A bursting fracture of the vault which is of considerable extent with no indication of cerebral or dural hemorrhage nor other cranial injury does not demand exploratory operation. If linear fracture is present and if there is a hematoma beneath the scalp or marking the site of the contusion, the indication for operation is questionable, and the fact of fracture alone is immaterial. The cranial bones when cracked are not subject to displacement, as there are no muscular pulls exerted on them, and if death does not ensue, they heal quickly. Careful watching and rest, with study of the eye-grounds, increase in blood-pressure, decrease in pulse rate to, or below, 50 per minute, and manifestation of focal symptoms will furnish indication for craniotomy.

A punctured fracture of the vault with depression of bones, hemorrhage from within the skull, or the presence of brain tissue in the wound, calls, unless the patient is moribund or in great shock, for operative care at once. If the patient is unconscious, this can be given without anesthesia of any kind. The scalp wound is enlarged, its edges, if ragged and dirty, are trimmed clean, and, in simple depression of the outer table, an effort is made to pry up the bone after it is loosened. If the inner table is found unbroken, the piece of outer table may be replaced or entirely removed and the wound closed with capillary drainage. If the inner table is found cracked and depressed, with no evidence of hemorrhage beneath, it also may be pried up into place, or one small fragment may be removed and the others lifted up. This is in no sense a decompression; it is in uncomplicated cases a mere reposition. This is excellent treatment if the injury is not over the motor area of the brain and the concussion is of short duration. In the frontal region one must be sure that the frontal or other sinuses are not opened into on account of the danger or infection. If they are concerned, free drainage must be kept in for several days until the cranial vault has healed on the inner side.

Other depressed fractures may be tightly wedged or the bone may

be driven down into the cortex. The treatment for these consists in making an opening in the immediate vicinity as in an operation for trephining, raising of the bone, arresting of diploëtic and dural hemorrhage, and inserting of drainage.

Gunshot fractures and injuries of the skull and brain develop special indications according as they occur in civil life or in battle. Under the conditions of civil existence, they are cared for in accordance with the treatment for punctured wounds given above, with drainage and without operative procedure on the brain. In war, with poorer hospital and other service, conditions are altered. Friedrich[1] classifies them as shallow injuries, caused by grazing or rebounding shots, and deep injuries caused by penetrating shots with or without wounds of exit. He also divides them into wounds of the base and of other regions of the skull. In severe comminuted injuries from penetrating shots immediate operation or attention by a skilled surgeon should be given on the field or nearby. It is not necessary to remove all bone fragments, but the skull should be spared as much as possible, and merely those lying free in the wound or pressing on the brain should be taken. Too active early interference gives poorer results than expectant treatment. Local anesthesia and morphine should be used in preference to general anesthesia.

Except for local attention to wounds of exit and entrance, expectant treatment is indicated in injuries of the skull base, arising from penetrating shots and from grazing shots with cerebral hemorrhage. Symptoms of excess of intracranial pressure, speech disturbance, and other disturbances of focal character are also treated expectantly unless rapidly progressing. Even a technically correct early operation may not avoid infection, and the cause of most late increases in pressure is infection, which should be searched for and drained through one of the wound openings.

A case of gunshot injury of the cavernous sinus has been recorded by Streissler.[2] The threatened loss of the eye on account of a neuroparalytic keratitis and an abducens paralysis furnished indication for operation to remove the bullet, which was successfully performed.

Non-puncturing Trauma of the Head; Bursting Fractures.—With or without Scalp Wounds.—In a certain percentage the indications for craniotomy are based on the following points:

1. The violence of operation must not increase the damage already done.

2. There must be reasonable possibility of relieving some or all symptoms.

3. A fairly accurate diagnosis of the pathology present must be made on the symptoms and physical findings, and the lesion must be stationary or progressing; that is, muscular weakness must become paralysis and twitching become convulsions.

Hartwell[3] believes that a further condition should be imposed,

[1] Beit. z. Klin. Chir., 1914, xci, 271.
[2] Deutsch. Gesellch. f. Chir., 1914.
[3] Ann. of Surg., xlviii, 25.

namely, that one must be reasonably certain recovery will not take place without operation. The author does not agree with this any more than he would agree to a statement that no abdomen should be opened for an attack of appendicitis unless it were reasonably certain recovery would not take place.

Immediate indications arise from progressive symptoms and signs enumerated above, practically all of which are caused by increased intracranial pressure. The early rise of pressure generally has its source in the extravasation of blood from injured cortical vessels; that coming later, accompanied by a free interval of consciousness, is probably caused by extradural meningeal hemorrhage, and the long-delayed symptoms usually by slow oozing from the cortex, or edema of the brain. This last group may take onset from twenty-four

FIG. 54.—Decompression at site of head injury. Wound nine days after operation, drain removed, scalp sutures removed and wound healed. Recovery.

hours after the injury and give prominent symptoms of headache, vomiting, and choked disk.

Indications for decompression which are more remote are found in the rise of temperature and increase of cerebral tension with headache, etc., which denote abscess. Meningeal infections are usually quicker in onset and spread more rapidly, although it is impossible clinically to differentiate meningitis from cerebral abscess in an early stage. A cerebrospinal fluid containing evidence of pus and under increased tension is sometimes found in meningeal cases. Abscess may develop and give symptoms months after injury, and it must be suspected in cases of rapidly increasing evidence of mounting pressure and temperature.

Epileptic attacks, paralysis, or chronic headache and threatened

blindness from cranial changes and pressure are late indications for decompression and cerebral operation.

Decompression can be performed at the site of injury, or at a point of selection according to symptoms of localized pressure or involvement of a known area of the cortex, as in paralysis or epileptiform attacks, or for general purposes in the temporal region, as advocated by Cushing.[1] He enumerates advantages of this last operation:

1. Approach through the thinnest part of the skull
2. Opening made under the temporal muscle, the fibers of which are split. When sutured it furnishes a good covering for the bulging cerebral contents.
3. If the middle meningeal artery or its branches are ruptured, the extradural clot is brought into view and the vessel can be ligated.
4. Subdural hemorrhage, from beneath the tips of the temporal and the base of the frontal lobes, which are most often injured, can be drained.
5. A large percentage of the lines of bursting fractures seek the mid-cranial fossa; hence free bleeding from the base is most easily drained by gutta-percha under the temporal lobe through an approach *via* the temporal fossa.
6. Subsequent edema and swelling of the brain which is responsible for most symptoms during the first two weeks can be combated by this opening.
7. Besides favoring an early subsidence of the acute symptoms, this operation lessens the late sequels and traumatic neuroses.

Necropsy findings generally include severe damage to the inferior surfaces of the frontal lobe of the brain, but there is no gross evidence of injury sufficient to cause death, which must have followed on account of swelling and edema and resulting circulatory changes. Early decompression permits expansion of the brain within its tight envelope, and as swelling is sure to follow in brain tissue as in any other soft tissue during effort at repair, the operation should be undertaken more often as a prophylaxis than it is. The decompression favors a free circulation and accommodation to early and late hemorrhage.

Blair[2] attempted to verify the value of early decompression in dogs which were struck a measured blow on the head. His findings were that such animals not operated on showed basal clots, but those on which immediate subtemporal decompression was done did not have any basal clots, or had none on the side which was drained. He also cites a series of 63 cases not operated on which lived more than two hours and of which 35 per cent. survived; while of 42 operated cases, 57 per cent. survived.

Technic of Subtemporal Decompression.—One-half of the head, or only that part over the temporal region, is shaved dry and iodine applied. Either a curvilinear incision with the base downward or an oblique vertical incision is made in the temporal region. Hemorrhage from the scalp is difficult to control by ordinary methods as the opened vessels retract into the thick scalp and cannot be picked up.

[1] Ann. of Surg., xlvii, 641.
[2] Jour. Am. Med. Assn., lxiii, 863.

The whole thickness of the scalp must be caught in the forceps or some other means of hemostasis secured. An easy method is afforded by a heavy rubber tube stretched around the head just above the ears and tightened. This has a tendency to slip off or to get in the way of the base of the incision. Howzell's pressure forceps, one blade of which passes under the scalp, the other above, taking in a large area between, is also used. These are good, but are cumbersome and get in the way. Heidenhain's interlocking mass suture is also used, but is not fully efficient. Wood[1] devised a rigid external metal frame to fit about the cranium, divided into quadrants united by hinged arms threaded with thumb screws. Within this, next to the scalp, is an inflated rubber tube with a valve stem like that of an automobile tire inner tube, coming out through a hole in the middle of the frontal rigid segment. On this is attached an atomizer bulb and a three-way cock for inflating and deflating. All parts can be boiled. Inflation of the inner tube compresses the scalp and stops hemorrhage; if slight oozing develops, a squeeze or two on the bulb controls it, and the constriction can be quickly removed by opening the cock. This is an improvement on Cushing's pneumatic clamp described in 1904. Landon[2] has also a metal tourniquet broken fore and aft with a self-locking ratchet to tighten the band.

The temporal muscle is exposed, split in the direction of its fibers and widely retracted. A trephine opening with the mechanical or hand drill is made, care being taken not to injure the dura, and the bone removed. A DeVilbiss forceps or the mechanical saw cuts off as much bone as is desired removed, extradural clots are lifted out if present, or hemorrhage is controlled by tying the middle meningeal. If hemorrhage from the diploë is uncontrollable, it may be stopped by Horsely's bone wax, or by bits of fascia or muscle taken from the operative field and jammed down into the bone. The Cryer spiral osteotome also controls hemorrhage from the diploë. If the dura is to be opened, it is wise to pick it up with a sharp, fully curved needle and a linen thread on either side of the proposed incision before cutting. This furnishes retraction and permits quick closure. The dura may be opened by multiple incisions. If hemorrhage is found, a thin, gutta-percha drain is inserted toward the base and brought out of the scalp wound, being removed in thirty-six hours. If no hemorrhage is found, but increased intracranial tension is found, it is wise to do a similar decompression on the opposite side. The bone button is left out, the temporal muscle sutured over the defect, and the scalp closed, with a capillary drain of twisted silkworm gut at one angle. It is not necessary to go into the details of brain operations in this work.

As a result of decompression with a small opening the dura and cortex bulge out strongly into the opening. They are protected by the temporal muscle and the scalp, and an enlargement in this area is not very noticeable. If decompression is done to relieve tension, the opening must be made of sufficient size to give relief. It

[1] Ann. of Surg., li, 646.
[2] Surg., Gynec. and Obst., xviii, 95.

has happened that edema with resulting paralysis results from a small area of cortex being caught in the bone hole. To avoid this, Hudson[1] advised a large scalp opening with a similarly large bone flap, quadrilateral in shape, cut through. This may be large enough to decompress a whole hemisphere. The bone is left and is held to the rest of the skull by small loops of silver wire inserted through drill holes and *tightened to give slack*, so that when the bone flap is extended to the limits of the wires there will be ample decompression. The scalp is closed over all. As the intracranial tension subsides the bone tends to come back into place and unites with a fibrous union.

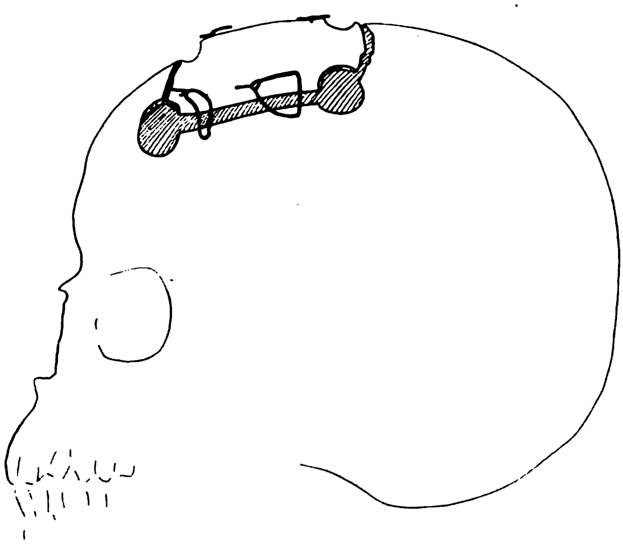


Fig. 55.—Decompression leaving the bone flap in place held by wire loops. Note the trephine openings connected by planes of separation made by the bone drill. This boy is alive and well, ten months after operation, and I believe is getting adherence between skull and bone flap. The unseen trephine openings are not on the opposite side of the skull, but seem to be on account of the angle of the roentgenogram. The longitudinal sinus was not opened.

Results of early decompression in accordance with the indications are becoming more encouraging. Ransohoff,[2] in 16 operations within twenty-four hours after accident, had 11 deaths and 5 recoveries. Cushing[3] had 2 deaths out of 15 decompressions, the 2 fatal terminations probably caused by the fact that unilateral exploration alone was performed. Lumbar puncture should be persisted in if it gives relief. Quenu reports 1 case[4] in which spinal puncture was performed on eighteen successive days with recovery. Ransohoff found that 37 per cent. died within six hours or less and 56 per cent. died within twelve hours, the fatalities occurring in spite of treatment.

[1] Ann. of Surg., lv, 744.
[2] Ann. of Surg., li, 796.
[3] Johns Hopkins Bull., xix, 48.
[4] Bull. et mém. Soc. de Chir., N. S., xxxi, 883.

CHAPTER IX.

FRACTURES OF THE BONES OF THE FACE.

FRACTURES OF THE NASAL BONES.

Anatomy.—The two oblong-shaped nasal bones lie in the middle of the face and form the bridge of the nose. They articulate above with the nasal notch of the frontal bone, laterally with the frontal process of the maxilla and below with the lateral cartilage of the nose. In the midline they articulate with each other. In addition they have anatomical relation with the vomer, the cartilaginous nasal septum, and the perpendicular plate of the ethmoid.

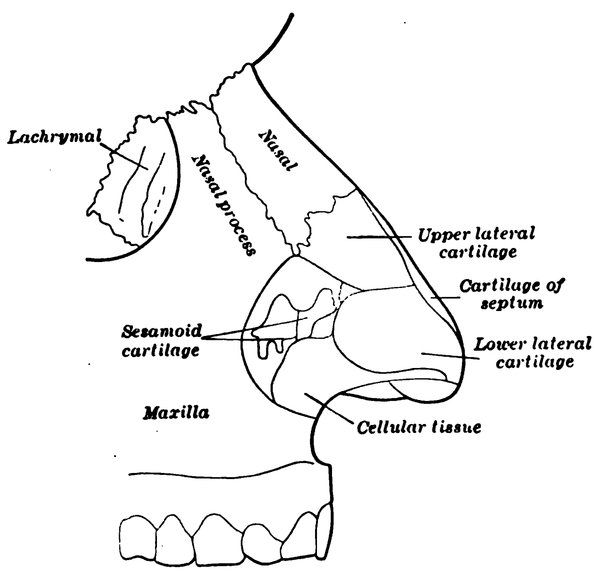


Fig. 56.—Side view of anatomical relations of the nasal bones.

Pathology.—The line of fracture usually involves both bones, and sometimes the neighboring bony processes. Many of the fractures are open either on the skin or on the mucous membrane surface. The line of fracture may be oblique or transverse, or, as in most cases, comminuted or multiple, the lower part of the bone suffering most. The displacement varies. The two nasal bones may remain united and may be separated from the frontal bone and displaced upward or more commonly downward and spread out. If they separate, they

extend laterally in direction of the cheek. Rarely one-half is fractured alone, or is separated at the junction with the frontal bone and displaced laterally or upward. The lateral cartilages are frequently loosened from the nasal bone and displaced, with injury also of the septum cartilage.

The cartilaginous septum may be torn from the vomer or from its attachment to the superior maxilla. It may also be broken in its body and thrust out into the nasal canal. Spontaneous septal deflections caused by fracture are likely to be angular, and they are later associated with cartilaginous or bony growths at the site of fracture. Most of the fracture lesions are located in the posterior two-thirds of the cartilage or the anterior half of the nasal bones. If the fracture

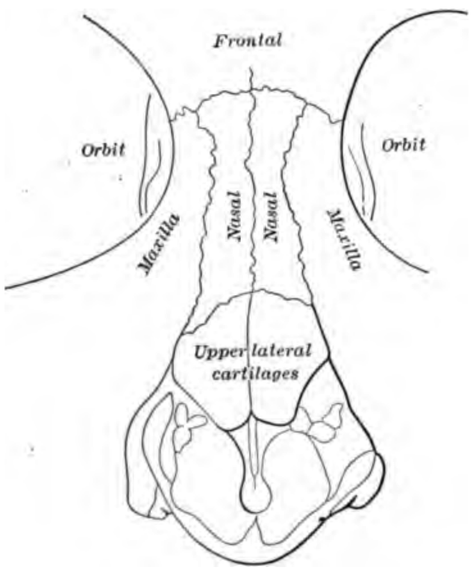


Fig. 57.—Front view of relations of the facial bones.

is greatly comminuted, both nares may become occluded by masses of bone or cartilage. This occlusion in children, after neglected nasal fractures, causes the patient to become a constant mouth-breather, with resultant changes which involve the teeth, palate, and jaws, as well as the chest development.

When the nasal bones are much displaced, the upper cartilage usually deviates with them, but the bone also may be displaced. Horizontal or oblique fractures are more common than vertical. Hematoma formation beneath the perichondrium of the septum is a common accompaniment of the fracture.

Infection from the skin or mucous membrane openings is frequent and leads to abscess, osteomyelitis with prolonged suppuration, and

cartilage destruction. The hematoma of the septum may become infected and cause late nasal abscess. Extension or complication of fracture into the cribriform plate of the ethmoid may cause interference with smelling sense, meningitis, or brain abscess. Emphysema involving the subcutaneous tissues of the nose, cheeks, and eyes may be caused by penetration of fragments into the tissues. Rarely the lacrimal duct may be occluded by pressure of an inflammatory process, or by bone fragments. Later nasal obstructions from septal deformities and inflammations are often seen. All the facial bones or those on one side may be fractured (see Fig. 58). Powers reported a case.

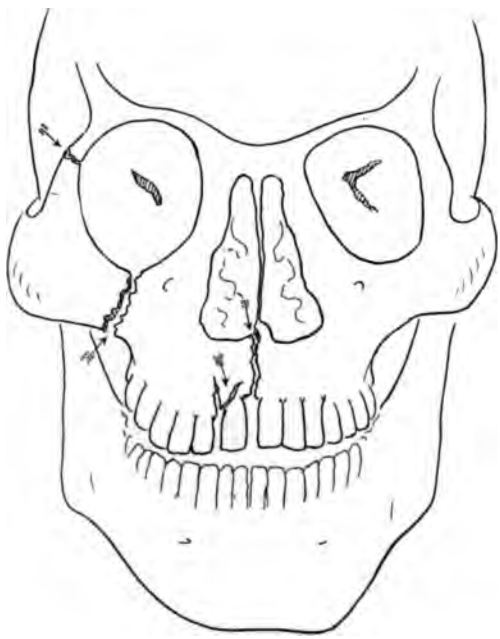


Fig. 58.—Fracture of one whole side of the face. Note the separation of the orbit zygoma, superior maxilla, and hard palate. Perfect recovery without infection. The cleft in the palate apparently healed promptly. Patient returned in a few weeks with an abscess of the face.

I have had 2 cases. One was unilateral with the line of fracture through the hard palate, superior maxilla, zygoma, and orbit. The whole side of the face was freely movable, with crepitus. There was ultimate bony union and complete recovery with practically no deformity. Many of these severe accidents are caused by headlong pitches on the face in bicycle falls or automobile collisions. Körte[1] records a case and calls attention to the serious character of the type, on account of possible meningitis.

Symptoms.—Pain, hemorrhage from the nose, deformity and swelling follow in order after fracture. The primary deformity, caused by

[1] Deutsch. med. Wchnschr., 1913, p. 253.

misplaced fragments, is often quickly enhanced by the subcutaneous swelling of hemorrhage into the injured area, which obscures definite deformity. Crepitus is usually felt when the nose is grasped gently and manipulated. Emphysema of the tissues may develop, or the lacrimal obstruction may cause an epiphora on the affected side. There is obstruction in the nares, often with severe nosebleed, and intranasal deformity is found when the nose is examined by reflected light. The prognosis is good. The danger to life is small, what there is being mostly from infection and cerebral complication. Reposition and correction of deformity is often very difficult, so that the prognosis of deformity is under ordinary circumstances only fair.

Treatment.—If there is severe nasal hemorrhage, the first step in treatment is to arrest this. Cold applications or sprays of adrenalin chloride solution, 1 to 1000, may be used, and if they fail the nares are packed with narrow gauze strips or plugged from the rear by gauze. Deformity of the cartilaginous septum must be ascertained. This is done by cocainizing the nares and examining with reflected light. Gross deformities of the septum and bones demand prompt reduction and general anesthesia is often necessary. These bones unite quickly, and angles formed by misplaced fragments fill up with blood-clot and exudate which prohibit delayed reduction after a week.

To accomplish reduction the surgeon places his left hand and forefinger on the deformed bridge. He inserts a flat, narrow periosteotome into the nostril on the side of the greatest deformity and elevates the nasal bone on that side into position. I frequently use a Kocher director in adults. The other nasal bone is dragged into place by the adhering tissues and they are both approximated in the middle by gentle pinching with the fingers of the left hand. The displacement will not tend to recur often except in cases of great comminution or in severe injuries of the septum. If the bone will not remain in place attempts may be made to hold it up by packing the nares with gauze. This holds the fragments up from within, and externally little splinting is required, as the tendency to displacement does not come from external source. External splints to correct lateral angulation have little value. Tin may be moulded to fit the nose and forehead for holding the alignment of the bridge, but there is always danger of compression on the secondary swelling, and the splint cannot be steadily maintained. The head portion is fastened by a head band, but it tends to slip and requires frequent adjustment. Cobb's splint consists of a metal head band held on by straps with an adjustable arm attached to a swivel like a head mirror. This has a padded extremity which makes counter-pressure on the displaced side of the nose. It is open to the objection made to any splint which produces pressure. When displacement cannot be retained by simple means, attempts to reduce the deformity should be repeated until success follows after the acute swelling begins to subside. Open operation is rarely indicated, but intranasal bracing or plugging with gauze is justifiable.

The internal deformity involving the septum and nares is as important as the external. Internal examination will assure the surgeon that the septum is in good alignment; if it is not, it should be replaced and the anterior nares packed to hold it. If there is great swelling or tendency to hemorrhage, it is better to give a guarded prognosis, let the septum heal, and look forward to a later submucous resection by competent hands. If there is suppuration the nose must be irrigated several times a day by a mild alkaline antiseptic wash to keep it clean and to favor free drainage. Secondary abscess in the cartilage or posterior nares must be drained and irrigated.

Old fractures of the nose are treated either by intranasal operation or by an opening through the skin externally below the bridge. A small longitudinal skin incision permits retraction upward to allow a narrow chisel to cut through the ascending process of the maxilla and the base of the nasal bone. Both sides are freed and the bones are pushed up into place, if they are flattened out. A projecting edge of the maxilla which causes deformity is also chiseled off through the original skin opening.

FRACTURES OF THE MALAR BONE.

Fractures of the malar bone are not frequent. I have had four in the last two years, two of which were operated on. In Cook County Hospital in the last eight years there have been seventeen fractures of the malar bone.

Anatomy.—This bone is exposed to violence on account of its position, but its flat surface, its thick body, and its four supporting processes give it great strength. Extending posteriorly is a strong process which unites with a similar process from the temporal bone to form the zygomatic arch, which is the strongest support the malar bone has.

The malar bone is injured by direct violence from blows or kicks on the face. The fracture may involve the body alone, as a depression or linear crack, the suture lines connecting neighboring bones may be disrupted, or the adjacent structures, especially the superior maxilla, may be fractured at the same time. The zygoma is also often fractured alone and the frontal bone, the base of the orbit, and other structures may be involved. Stimson[1] mentions 2 cases of fracture of the zygomatic arch from within outward by falls on sticks held in the mouth. Rarely the temporomaxillary joint is involved, and the coronoid process of the mandible is broken.

Symptoms and Diagnosis.—Although the bone is subcutaneous, it is difficult to palpate because it merges with surrounding bone. Both cheeks should be examined simultaneously, the surgeon standing behind the patient to feel the zygomatic arches. The facial skin and tissues are freely movable upward, and the malar process of the superior maxilla, the lower border of the orbit, and the zygomatic

[1] Fractures and Dislocations, 1912, p. 174.

process of the frontal bone can be all outlined. By comparison of the two sides variations in the position of the interlying malar bone can be made out, the lower border being also palpable by fingers hooked under it back to the temporomaxillary joint.

Deformity caused by depression or lateral displacement of the bone with swelling, mobility, and crepitus are the diagnostic symptoms. The ecchymosis and swelling about the orbit may obscure these findings for a few days, or if the fracture is open the loss of bone continuity may be seen, or felt by a probe. Function of the jaws is seldom interfered with unless there is fracture of the coronoid of the mandible, but there is usually some pain in mastication because of proximity to the insertion of the masseter muscle. Mobility of the bone and crepitus can be detected by one grasping the zygomatic arch on the inferior margin and rocking the bone. If there is a diastasis or linear crack, no crepitus will be obtained. Cracks and separations extending into the orbit may be palpable, or the overlapping displacement of the malar bone on to the superior maxilla may form a definite palpable ridge, as in one of my cases.

When the displacement pinches the infra-orbital nerve, or the superior maxillary nerve is bruised, there is pain or anesthesia in the face, lip, and teeth corresponding to the nerve distribution. The same symptoms are produced by the pressure of extravasated blood and swelling, which may also displace the eye. If the superior maxilla is involved in the fracture, the maxillary sinus may be opened, and there is hemorrhage from the nose with danger of secondary infection. The bone tends to unite quickly and with little callus. Deformities remain permanently unless reduced, and the question of treatment rests almost entirely on the displacement or the symptoms of nerve pressure.

Treatment.—Open fractures must be cleansed and drained, and small loose bone fragments must be removed. Replacement can be done at the same time, and a retentive dressing holds the bone in place, particularly when the zygomatic arch is broken. Depressions are very difficult to raise without open operation. The use of hooks inserted subcutaneously has been suggested, but they are unsatisfactory. When there is deformity in the zygomatic arch or at the junction of the superior maxilla, or a depression deformity with interference with jaw function for any reason, open operation is indicated. Gibson reported a case[1] in a man of twenty-two years, who fell against a sharp object. There was immediate limitation of movement of the lower jaw, which was recovered from after open operation and reduction of the malar fracture. Likewise, nerve pressure with sensory disturbances of the teeth indicate open operation, but not until time has elapsed to permit absorption of extravasated blood which, instead of bone, may have been the cause of pressure.

Open operation means a scar on the face, and the patient should make a choice between the bone deformity and the skin scar. If the

[1] Ann. of Surg., lv, 457.

zygoma alone is fractured and depressed, it may be raised by a narrow chisel or periosteotome through a quarter-inch incision parallel to and below the arch. A wire suture passed under the fragment may permit it to be elevated into position. When the whole malar bone is depressed or there is deformity involving the function with the superior maxilla, it is almost impossible to raise the fragment except by open operation. Involvement of the maxillary sinus may permit the elevation of bone by an approach through the mouth, an opening into the antrum and the prying up of fragments from within. There is little tendency to recurrence of deformity, and the only care needed is to avoid pressure on the bone until union has followed. This takes from two to three weeks. Old cases with depression and union or nerve involvement sometimes come for operation. In these I make a small curved incision over the junction of the malar and superior maxillary bone and raise a flap of soft parts. If there is solid bony union, the depression cannot

FIG. 59.—Result after an open fracture of the malar bone. The scar became adherent to the bone, pulling the lower lid down so that the eye could not be closed. Cured by operation to free the adherence.

be raised, but deformity caused from overlapping edges of either the malar or superior maxillary can be trimmed down level by a chisel. When the supra-orbital nerve is pinched by bone, the canal is widened by the cutting away of a trough and pressure is thus relieved.

FRACTURES OF THE SUPERIOR MAXILLA.

The superior maxilla is irregularly shaped and bound to the contiguous bone as the malar bone is. It has strong borders which come in contact with the malar by the malar process, with the frontal, zygomatic arch and orbital bones, by corresponding processes. The body of the bone is well protected; its surface plates are thin and they form the boundaries of the maxillary sinus, the upper border of which lies at the malar process of the maxilla. Direct violence is the general cause of fracture, and other bones are often involved. The anterior wall of the antrum may be caved in by a blow, or the alveolar process

may be broken in the exertion of pulling teeth. The palatal suture may be separated with diastasis of other sutures. The malar bone is frequently driven down and impacted into the maxilla.

The infra-orbital or anterior dental nerves may be involved in the maxillary fractures, and hemorrhage from the nose is common when the antrum is broken into and its mucous membrane torn. Indirect violence is also a cause, from violence transmitted through the inferior maxilla, which forces the superior maxillæ apart. Brown[1] cites a case of his own and one of Dr. G. W. Fox's of Milwaukee. In the latter's case there was an opening through the incisor teeth and hard palate and division of the soft tissues caused by the forcing apart of the maxillæ. The zygomatic-maxillary suture also was disarticulated, and the examination by palpation revealed diastasis in the infra-orbital area.

Symptoms and Diagnosis.—There is often depression, pain, swelling, and nasal hemorrhage. These facial fractures occur from a mechanism which tends to drag them away from the skull rather than depress them into it, but rarely the superior maxilla may be deeply driven in and backward toward the pharynx. If the injured person is seen before the extravasation of blood and swelling an early diagnosis may be made by palpation, as described under the Malar Bone. Crepitus is often lacking. Ecchymosis in the hard and soft palates indicate fracture. There is always ecchymosis with involvement of the eye, and the swelling may be great. Many fractures are overlooked, however, until they have united. They are then determined by the deformity of the dental arches. Mastication is painful from involvement of the masseter and pressure of the temporal muscle. Intra-oral examination should be made that narrowing or dropping of the dental arch may be determined.

Treatment.—Some of these fractures are open on the skin surface, and they should be treated as are open fractures in any part of the body, by asepsis and drainage. The facial bones have an abundant blood supply, and it is best to leave *in situ* any loose fragments of bone, because they usually remain viable. Fractures opened from within the mouth through the mucous membrane, particularly those involving the alveolar margin, are also treated conservatively. An antiseptic mouth wash is provided. And, if the fragment cannot be held in replacement, the teeth may be wired or fastened by the interdental splints described under the Fractures of the Inferior Maxilla. No attempt should be made to withdraw loose teeth, because they often become firmly fixed in the sockets later, and traction on them may break off a portion of the fractured alveolar border. This breaking off opens up the bone surface to further chance of infection and must be avoided. Open fractures furnish opportunity for direct replacement of fragments. Wires to hold them are seldom indicated.

The course of closed fractures is one of considerable discomfort

[1] Oral Diseases and Malformations, 1912, p. 378.

because of the contusion character of the injury with the impaction of the bone. If the nerves are pinched, there is acute pain which calls for immediate reduction or the use of anodynes. After the swelling subsides the facial asymmetry is noticed, and untreated cases result in deformity. Complications from abscesses in the cheek or infra-orbital fossa, or empyema of the maxillary sinus are not common. They demand drainage and hot applications with vaccine therapy.

If the fracture can be reduced, the simplest treatment is to hold the jaws together by wiring or interdental splints. The dentist's modeling wax is heated in warm water, and after the bone is replaced the jaws are brought together on the wax, which when hardened acts temporarily as a splint. (See Fractures of the Inferior Maxilla.) A rubber or metal dental splint should be made subsequently by the dentist.

Some fractures are irreducible by manipulation and dental splints. These patients are also offered the alternative of deformity or open operation, but facial scar is not always necessary. The same external operative measures are used as were described under Fracture of the Malar Bone. The depression may be lifted into position by hook or wire and the fragments wired to each other. Usually all that is needed is replacement, with a slight impaction to hold the maxilla in position. Efforts to raise the superior maxilla by means of an instrument used inside the mouth are not very successful. That method will raise the zygomatic arch or the malar bone, but it fails to hold up the maxilla. Lathrop[1] recommends approach *via* the canine fossa, citing 7 cases treated in that way. He used general anesthesia administered through a nasal tube, the patient sitting erect. The nasal and maxillary fragments are elevated through a small horizontal opening in the mucous membrane on the canine fossa when the cheek is held back. If there is a fissure present in the bone, a narrow director is passed into it; if no fissure is present, an opening is made into the antrum, and a No. 24 French sound is passed in to force the bone into position. The antrum is then packed with a narrow strip of iodoform gauze to hold the fragments in position and to insure drainage. This is removed in four or five days, and the antrum for a few days is irrigated by an antiseptic wash through the mouth.

After-treatment, especially that directed toward feeding and oral asepsis, is very important. Most of these injuries are accompanied by shock of serious extent and this must be combated by stimulants and careful nursing. If the palate is split asunder, swallowing may be impossible, and all food must be given by a stomach or nasal tube. The nasal tube is better, as it leaves nothing to soil the mouth. When the patients are able to attend to themselves, order a glass to be kept filled with antiseptic mouth wash for their use every hour. Food should be kept out of the mouth when there is an opening into the facial bones, and a nurse should irrigate every two hours. (For nasal feeding see Fractures of the Inferior Maxilla.) Secondary

[1] Boston Med. and Surg. Jour., January 4, 1906, cliv, 8.

abscesses and osteomyelitis sometimes prolong the case. Sufficient drainage must be instituted, and every precaution taken to insure oral cleanliness and to ward off pneumonia.

FRACTURES AND DISLOCATIONS OF THE INFERIOR MAXILLA.

In 10,702 fracture cases admitted to the Cook County Hospital in eight years, 437, or 4 per cent., were fractures of the inferior maxilla. Dunning[1] gives a tabulated list of 1065 cases treated at the New York College of Dentistry, and he found that 28 per cent. of the cases occurred in the third decade of life, while 32 per cent. occurred in the fourth decade. Males predominated over females in the proportion of 992 to 73, approximately 93 per cent. to 7 per cent. These facts are

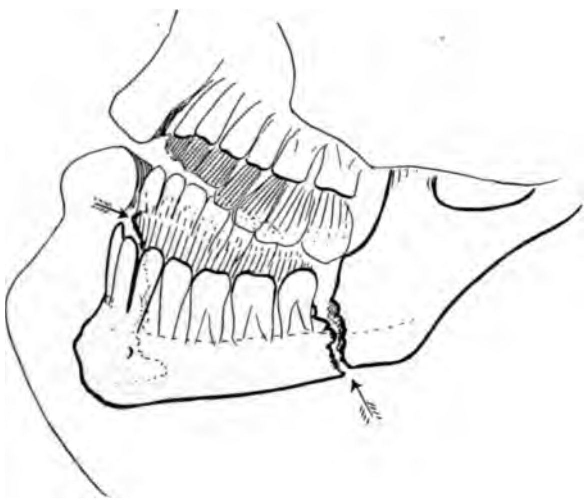


FIG. 60.—Double fracture of the inferior maxilla, one plane near the symphysis, the other just back of the teeth.

readily understood when one considers the exposed location of the bone, the occupations of men, and the frequent settling of disputes by fisticuffs. In Dunning's series fist blows accounted for 495 cases, or 46.5 per cent., falls for 140 cases, or 13 per cent., extraction of teeth for 5 cases, or 0.5 per cent., and pathological fractures for 2 cases out of the total number, or 0.2 per cent. Children rarely suffer fracture of the jaw. Fracture of the alveolar border, the pulling off of a small edge or splinter of bone, is a common result of tooth extraction and is not included in statistics. Complete fracture of the jaw caused by tooth extraction is relatively rare.

Double fractures on the same side or half of the bone are a little more frequent than on corresponding points of the two halves (Fig. 60). They are more painful and are often accompanied by partial

[1] Jour. Amer. Med. Assn., January 9, 1915, lxiv, No. 2.

dislocation if the two fractures are symmetrical and the bone arch loses its support. This permits the condyles to be partly displaced from the glenoid cavities. Single fractures predominate numerically, triple and quadruple fractures occurring rarely. In the 1065 fractures mentioned previously there was the following division:

Single fractures	951 or 89.0	per cent.
Double fractures	108 or 10.0	"
Triple fractures	5 or 0.5	"
Quadruple fractures	1 or 0.1	"

Fractures of the inferior maxilla may be divided into those of the body, median line or symphysis, ramus, alveolar border, condyloid process, and condyle. In the body and at the symphysis, the site and direction of fracture plane is guided by the direction and force of the causative direct violence and the presence or absence of teeth or foreign bodies held between the teeth (Fig. 63).

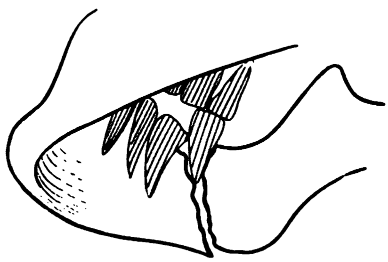


FIG. 61.—Fracture through the body of the jaw. Note the loosened tooth.

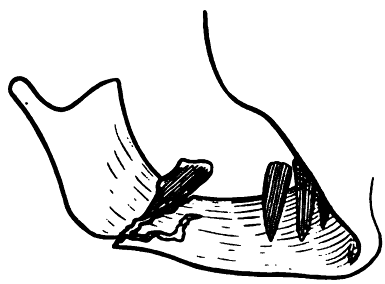


FIG. 62.—Fracture through the body of the jaw. The plane of separation has selected the alveolar process bearing a tooth.

The site of fracture is commonest in the canine and bicuspid region of the body of the bone. The weakest point is about the mental foramen, especially in an edentulous jaw. This point is the one where most blows land and is also weakened because many people lose the bicuspids or molars early in life. The ramus, symphysis, coronoid process, and condyles are less frequently involved. Impacted teeth in the mandible predispose to fracture at their location and they also hinder bony union. They are easily found by the Roentgen rays. A very large proportion of jaw fractures are open. Most are opened into the mouth through the gums and mucous membrane, which forms a scant covering over the bone, and which is easily torn when the teeth are displaced.

The displacements vary with the site of fracture. In the body the fractures through the canine region do not show much deformity but they are frequently obstinately displaced. In this region there is little opportunity for diverse muscle pull when the fracture is so near the midline, but the line of fracture is often oblique, and the fragments

tend to slip past each other if not firmly supported. Displacement in the bicuspid region may show marked deformity, as the anterior fragment tends to be pulled downward and backward by the hyoid muscles, and the posterior fragment is drawn upward by the masseter and pterygoid muscles. The same facts regarding displacement apply to the fractures in the molar region, which usually exhibit deformity. These injuries are likely to pinch or lacerate the inferior dental nerve.

Fractures back of the teeth are not common. Through the angle of the jaw they are oblique from above downward and backward. In the ramus the fracture is also oblique or vertical, depending on the

Fig. 63.—Incomplete jaw fracture through a lone tooth, the jaw being quite edentulous. There is no separation.

character of the causative blow. Displacement is limited by the strong supporting muscles on either side.

Fracture of the Condyle of the Inferior Maxilla.—The causes are direct violence, which drives the jaw backward and upward, or violence applied directly over the side of the face. Fracture of this process is probably quite frequent and is solitary, not accompanied by injury of the other facial bones in all cases. Roe[1] found six condyloid fractures in 41 cases examined by him, and Egger[2] gathered together 365 cases of simple fracture of the mandible of which 4.1 per cent. involved

[1] Ann. of Surg., August, 1903, p. 221.
[2] Beitr. f. klin. Chir., 1913, lxxvii, 294.

the condyle. Multiple fractures of the lower jaw and of the facial bones involve the condyle more frequently, the percentage rising as high as 10, according to Egger. Dunning's figures show the condyle involved in less that 1 per cent. Ivy[1] collected 45 instances of fractured jaw and found but 1 case of condyle fracture. Both condyles may be broken by the force. The anterior wall of the external auditory meatus may be crushed in, or the glenoid cavity of the skull may be cracked and depressed. When the ear canal is involved and the condyle is intact, there are symptoms of occlusion of the canal when the jaws are closed or the inferior maxilla is forced backward. If the glenoid cavity of the skull is fractured, there is possibility of infection and brain abscess or ankylosis in the joint. Some effort should be made to determine whether the fracture is extra- or intra-articular, because the distinction has a bearing on both treatment and prognosis. Most condylar fractures are through the neck and are extra-articular, and there is little displacement, because the fragments are held by the periosteum and surrounding ligaments and soft tissues. If both condyloid processes are broken, the lower jaw is drawn up and backward, and there may be considerable movement in the joints. There is continued pain and a tendency for the small fragments to necrose or become absorbed. Unilateral fractures cause swelling around the temporomaxillary joint, ecchymosis and pain from joint movement, and exhibit a mandible drawn toward the fractured side by the opposite internal pterygoid muscle. Crepitus can often be felt by a finger placed over the point of tenderness when the jaw is moved. Unilateral dislocation is distinguished from the unilateral condyle fracture by the fact that the jaw is pulled toward the normal side in dislocation. Other differential points between unilateral dislocation and condylar fractures are: in fracture there is crepitus, and the jaws can be closed, whereas in dislocation the jaws are open, there is no crepitus, and the chin is deflected away from the injury. In some cases the broken-off articular surface of the condyle may be displaced forward and inward. It is pulled upon by the external pterygoid muscle and can be felt by one pulling the jaw forward, placing the finger in the upper lateral pharyngeal wall, and pressing outward. The portion of the bone below the process is drawn upward and outward by the masseter muscle (Fig. 64). Union may occur with this displacement without ankylosis, but with the chin deviated toward the injured side. Reduction accomplished by the means mentioned may be satisfactory and permanent. These fractures go undiagnosed after falls followed by coma or unconsciousness. They are not noticed until the patient recovers to find that the teeth are not in alignment.

Involvement of the temporomaxillary joint in intracapsular fracture influences treatment to the extent that moderate joint motion must be encouraged from the first to avoid ankylosis. Roy[2] advises against the use of interdental splints in condyle fractures for fear of ankylosis.

[1] Ann. of Surg., lxi, No. 4, p. 502.
[2] L'ondontologie, 1913, xlix, 481.

If the smaller fragment is widely displaced, or if ankylosis threatens to ensue, the fragment should be excised and an atypical arthroplasty should be done at once with the use of any tissue in the neighborhood to cover the bare bone end.

Fractures of the Coronoid Process.—Fractures of the coronoid process are rare, because it is protected from direct violence by the zygoma and from indirect violence by mobility. Whether fracture of this process may be caused by contraction of the temporal muscle has not been demonstrated. Usually fracture of other facial bones accompanies this injury. In Dunning's series there were two coronoid fractures. The dangers of joint ankylosis and treatment are like those of the condyle.

Symptoms and Diagnosis.—Fractures of the mandible have most of the cardinal fracture symptoms. Pain and tenderness are always present. There is abnormal mobility of the bone, which is easily apparent to both the patient and surgeon, and is proved by the lack of power in the jaw. Crepitus is present and is demonstrated either

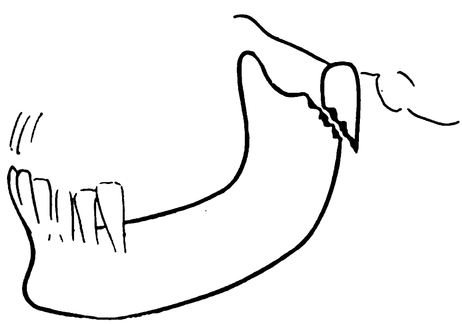


Fig. 64.—Fracture through the neck of the condyle of the mandible.

by the attendant's taking the jaws between the fingers and moving them or by his having the patient bite. The patient feels the bone slip and has simultaneous pain. There are often hemorrhage and swelling in the external soft parts, from the trauma received or the tearing of the periosseous tissues. Within the mouth the line of fracture may be visible at a glance, the malalignment of the teeth showing prominently, and the bleeding, torn line of separation through the mucous membrane standing out. There is increased salivation from reflex nerve stimulation or pain, drooling is present, and there may be a copious bloody expectoration. The patient does not talk plainly, he cannot close the jaws firmly, and he very probably has loosened teeth. Double fracture causes greater deformity and loss of function, the broken-out piece tending to be drawn down and backward. After a couple of days, if infection has started, there is a foul breath, pus exudes from the torn gums, and swelling and abscess at the site of fracture follow. Later there is an inflammatory infiltration of the neck and face tissues on the injured side, cervical adenitis begins, and

the patient becomes more or less toxic from swallowing pus. Mastication is painful and is soon not attempted and there is sore throat and pain on swallowing. Deviation of the jaw depends on the site and multiplicity of the fracture, as previously described. Gunshot fractures from suicidal attempts when the bullet enters from the oral side, are characterized by loss of bone tissue and severe laceration of the soft parts. There is always great shock and hemorrhage. When the dental nerves are involved, there may be extreme pain from partial pressure, or anesthesia, when the nerve is severed or crushed. There is but one case on record of rupture of the facial artery in fracture caused by direct violence.[1]

Cases of jaw fracture of some days' duration always present swelling and edema with increasing pain. The gums are swollen, and a discharging sinus may lead to the bone, where there are loose and necrotic fragments of varying size. The fragments are not large as a rule, and extensive loss of bone from infection is uncommon. Even in the presence of infection bony union occurs in four to six weeks. Secondary abscesses, sinuses, or discharge of necrotic fragments may have occurred in the course of the recovery, but non-union is very rare. I have had a case of double fracture this year, one line passing obliquely through the bone at the angle, the other through the symphysis. Operation was performed on the posterior fracture, and the symphysis was held by a bandage. After eight weeks when the angle was firmly healed, the symphysis still permitted motion. Union finally occurred. In Dunning's series of 1065 cases there were but 2 cases of non-union.

Prognosis.—The prognosis is favorable in most cases. When other facial bones are injured, there is danger of serious shock. There are other dangers from pneumonia, brain abscess, and general sepsis from swallowing and absorbing the pus secretions in the mouth. Even with abscess formation and bone infection the outlook is favorable with efficient drainage.

Treatment.—Because infection is the main thing to be considered in all fractures of the jaw, even in the small percentage of closed cases, first attention should be directed toward oral cleanliness. To obtain this, as well as to carry out the best line of treatment, the services of a dentist should be secured. Closed cases are likely to become open by pressure of bone fragments, sloughing of gums and mucous membrane, or loosening of teeth in the fracture area, and every case of mandibular fracture should be prepared with a view to the care of infection locally and generally. The teeth must be carefully cleaned, and old loose and infected roots should be removed, if there is not too much pain in the jaw. The patient should use an alkaline antiseptic mouth wash if he is able, cleansing the mouth out gently every hour. When other injuries or the general condition renders this cleansing impossible, the attendant should wipe off the teeth with soft cotton swabs every two hours. The mouth wash reduces the

[1] Cramp, Med. Rec., New York, September 21, 1911.

bacterial activity, soothes the swollen mucous membrane, and promotes drainage of sinuses. When infection is established in the bone, hydrogen dioxide must be added to the irrigating solution. Fractures opened by external wounds through the soft parts of the face are drained and partly closed after thorough cleansing. The facial tissues

FIG. 65.—Beginning of the second turn of Barton's bandage.

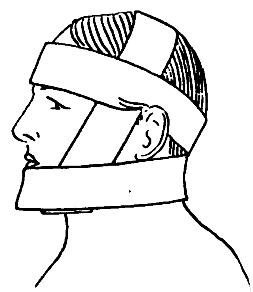


FIG. 66.—Gibson's bandage for the jaw.

are so vascular that they are able to overcome infections which would get the better of other tissues. In ordinary practice after mouth cleansing has been started we apply a flat ice-bag to the side of the face and hold the jaw in a partly restricted and comfortable position by a bandage.

Further treatment is divided among the following procedures:

1. External bandage and splints applied to the head and jaw, such as Barton's bandage, wire splints, plaster-of-Paris dressings, and

FIG. 67.—Crossed bandage of the face used for mandibular fracture.

FIG. 68.—Plaster-of-Paris bandage for fracture of the mandible.

various other retentive splints to hold the jaw externally (Figs. 65, 66, 67, and 68).

2. Efforts to effect dental occlusion by wiring the teeth, temporary and permanent interdental splints, and a combination of internal and external splints like Matas's.

3. Surgical operative procedures consisting in wiring the body of the bone or applying other types of internal bone splints.

Laying aside the necessity of oral cleanliness outlined previously we must select a type of treatment which aims at immobilization, perfect approximation of the fragments and dental alignment, opportunity for taking food and possibility of inspection of the parts. To these desirable features one might add a provision for some freedom in the use of the jaws, but that is not essential. The most important function of all is perfect dental occlusion, so that the patient may retain his bite and mastication power. Carmody[1] states that over 200 methods of treatment have been devised for fracture of the jaw. Only a few of known worth will be described.

1. External bandages in ordinary use are Barton's and the four-tailed bandage. They must be watched to prevent slipping and stretching. For preliminary treatment they offer much comfort and a substantial support. Other external splints made of wire or metal are padded to fit outside the lower jaw and are strapped or bandaged into

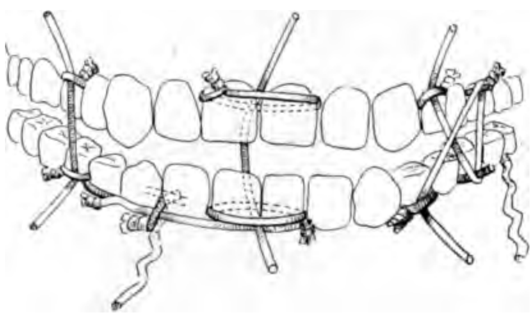


FIG. 69.—Angwin's method of wiring the teeth for fractured mandible.

position. The dentist's modeling compound may be moulded to fit the outside of the jaw and held on by bandages. Alcoholic patients who will not keep a bandage on can be dressed with broad bands of adhesive around beneath the jaw and over the top of the shaved head.

2. Wiring the teeth, that is, wiring the teeth of the two jaws together to hold all in position, is an old procedure. Gilmer first described it in 1887.[2] There are many methods of doing this, in all of which precaution is taken to avoid putting stress on the teeth which approximate the fracture site lest they be loosened. More distant teeth are selected, and the wires, copper or German silver No. 24 gauge, are anchored around the base and twisted into a long strand on the outer surface. These long strands are then twisted together from above downward across the fracture site to hold snugly, with the cut-off ends bent in toward the teeth. The dental alignment should be perfect, and the wires will need watching and tightening. They should

[1] Military Surgeon, 1914, xxxiv, 542.
[2] Arch. of Dentistry, 1887, p. 388; and International Congress, 1904, p. 185.

remain in position thirty to forty days. The disadvantages are that the patient has to subsist on liquid diet which he sucks through his teeth, and that the teeth are liable to loosen under the continued strain. A very excellent method of wiring has been described by Angwin,[1] for illustration of which see Fig. 69.

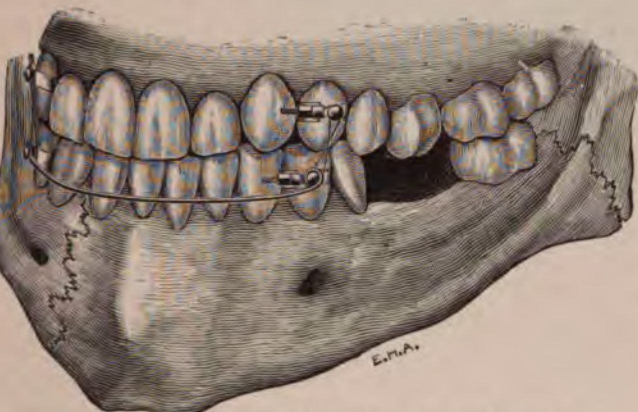


Fig. 70.—Splint for fractured lower jaw. (After Angle.)

The greatest objection to Angwin's method is the wiring of the central incisors, which I have found in some cases impossible. Angle's bands are also a similar and possibly better method of holding the jaw in corrected position. They are bolted on (see Figs. 70 and 71. Figs. 72 and 73 show Angle's and Löher's splint). If the

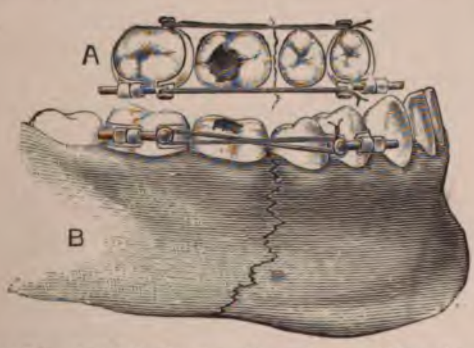


Fig. 71.—Splint for fractured lower jaw. (After Angle.)

jaws are wired while the patient is under the influence of a general anesthetic, the nurse should be provided with a pair of wire clippers to be used if there is a postanesthetic vomiting. Suffocation and aspiration pneumonia are the dangers.

[1] U. S. Navy, Med. Bull., Washington, 1911, v, 332.

After wiring of the jaws the patient may be fed by means of a small rubber tube passed along the gum margin to a point behind the teeth. Nasal feeding, as performed in gavage on children, is also practical and causes no inconvenience if the patient coöperates. A rubber tube is needed, small enough to enter through the nostril. It is passed in

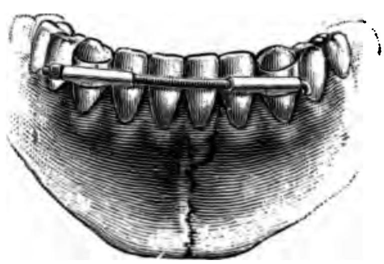


FIG. 72.—Splint for fractured lower jaw. (After Angle.)

well lubricated after a cocainizing of the anterior nares with 5 per cent. cocaine solution. When the tube enters the esophagus liquid food is slowly passed in by a small glass funnel held above the level of the highest bend of the tube. After the feeding is completed, the tube is washed out with sterile water and then withdrawn. This

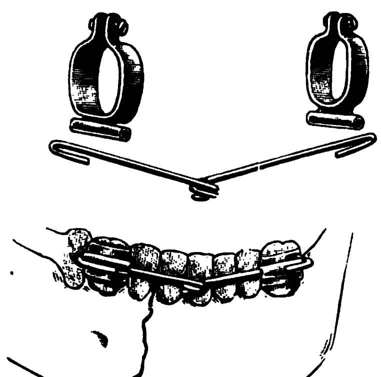


FIG. 73.—Löher's splint. (Brown.)

prevents contamination of the nares with food. Through a combination of nasal feeding and constant lavage of the mouth the oral infection is reduced to a minimum.

Temporary interdental splints are made of dentist's modeling compound, which should be at hand in every hospital. This compound is softened in warm water, a suitable piece is placed between the jaws, and the teeth are closed on it. The jaw is brought into alignment,

but the mouth need not be closed. After the impression is made, the compound is removed and allowed to harden fully. A hole is cut out of the middle through which food and liquids can pass. The splint can be used permanently if one takes the precaution to use cold solutions for feeding and irrigating the mouth. Warm fluids soften the compound and change its shape.

Permanent interdental splints, that is, supports placed between the jaws, were first used by Hayward in 1858. Reduction and perfect alignment of the teeth are necessary before they are fitted. Individuals who have multiple fracture or who have much pain and are very nervous may require a general anesthetic preliminary to reduction. With the fracture reduced if possible, an impression of the teeth is made with the modeling compound. This is removed and hardened, and plaster cream is poured into the mould. This gives a plaster cast which represents the exact condition of the teeth. After it has hardened the plaster may be sawed through at the fracture site if reduction is not perfect and the alignment of the plaster cast is corrected. Over the plaster is fitted a rubber or metal splint which can be cemented on to the teeth to hold the jaw perfectly reduced. With this apparatus the mouth can be opened and soft food can be eaten.

There are some soft interdental splints which have arms and prolongations externally for fixation by bands around the head or neck. Kingsley's interdental splint is an excellent one (see Figs. 74 and 75). Green[1] describes an external internal splint to give fixation to the jaw without the use of bandages.

Matas's splint[2] is a combination of interdental splint and external chin support which can be bandaged on (see Figs. 76 and 77).

Gunshot fractures which cause loss of bone continuity can be held in position by a dental bridge splint on the injured jaw. Patterson[3] cites a case treated in this manner, in which he obtained a new growth of bone to fill in the hiatus.

3. Operative procedures on the bone are not often indicated. The ramus of the jaw is never operated on for fixation. The condyle and coronoid fractures have been discussed. The two surgical methods of jaw fixation are plating and wiring. The operations are performed through a small skin incision just below the curve of the cheek. The muscle fibers are split rather than cut, and the fractured ends are bared enough to permit hole drilling. One or two wires are fastened through to hold the fragments, or, if a plate is used, it is frequently applied on the under side of the jaw as far from the mouth as possible. A small two-screw plate is used. Formerly wires were twisted together and turned down against the bone, the external incision being closed tightly. Recently when I have done the operation of wiring I have left the wire ends long, twisted them up firmly to secure apposition, and let them protrude from the incision, which was not sutured at

[1] Internat. Congress, 1904, ii, 183.
[2] Ann. of Surg., 1905, p. 1.
[3] Western Dental Jour., 1891, p. 635.

all. Free drainage follows from the wound from the start, and when infection sets in it is mild and drains along the wires. As a result, bone union is prompt. The wires are pulled out after three weeks, and the wound gradually closes with slight discharge for two weeks more. I find that these cases leave no permanent bone infection, and the patient appreciates the necessity for drainage.

FIG. 74.—Kingsley's splint. (Stimson.)

The objection to wiring and plating operation is that perfect apposition is not secured and that there is always infection with an ugly scar when abscesses form. These are valid objections, and open operation is seldom performed except in multiple fractures or those double

FIG. 75.—Kingsley's splint applied. (Stimson.)

cases near the angle which cannot be satisfactorily held when the body is fractured farther forward. I have never seen a wiring or plating operation of the jaw which did not necessitate the removal of the foreign material. Plating, I believe, is never called for. Wiring with constant drainage is less objectionable.

The type of splint or dressing depends on the site of fracture and the surgeon's familiarity with the method. An oral surgeon or dentist

Fig. 76.—Matas's splint for fracture of lower jaw.

Fig. 77.—Matas's splint.

should coöperate in every case. The splint which fulfills the requirements of the largest number of fractures is the interdental splint of rubber or metal which is moulded and made to fit the individual case (Fig. 78). In fracture through or near the symphysis, when the teeth are sound, a cap splint cemented on allows the patient to open the mouth and to masticate. In the molar region the same type of splint can be used, if the teeth are in good condition. If they are not, the two jaws are wired together for a couple of weeks, and a cap splint can then be applied until bony union is firm. Back of the teeth, fracture through the angle and ramus are held by interdental splints, wiring, or Angle's bars, and surgical operative procedures are used in obstinate deformities, especially in double fractures.

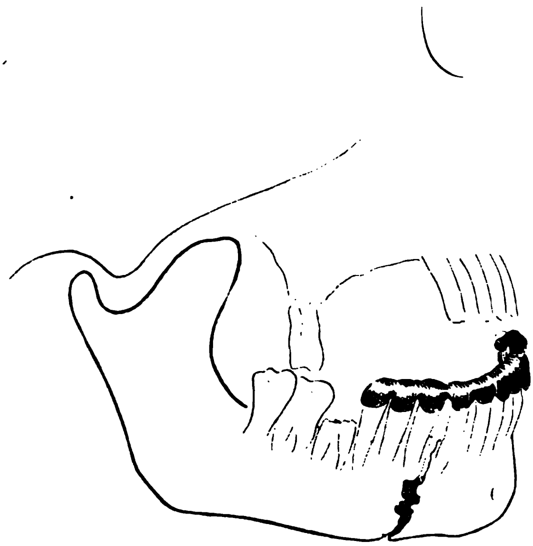


FIG. 78.—Reduction of fracture of the mandible held by an interdental splint.

DISLOCATIONS OF THE LOWER JAW.

Dislocation of the lower jaw, according to Wullstein, represents 1.5 per cent. of all dislocations. In the 775 dislocations collected at the Cook County Hospital there were eight involving this bone. Only a proportion of these dislocations are hospital cases, as they seek professional aid at the nearest point to relieve the urgent symptoms. The largest number of cases occur in women in midlife; they are almost unknown in infants and are rare in adolescence and old age. Luxation is commonly forward. It may be backward or outward, accompanied by fracture of the skull or the mandible itself. Bilateral dislocation forward is more frequent than unilateral.

Dislocation Forward.—This injury is caused by muscular action in yawning and laughing. Direct violence alone or in connection with

muscular action may also cause luxation. A slight force depressing the lower jaw of a wide-open mouth is sufficient to cause forward dislocation. The pulling of a tooth, attempts to take large bites, or sudden jars of the head, are the usual causes. The temporomaxillary joint is covered by a capsule which is reinforced by two heavier lateral bands or ligaments and a strong stylomaxillary ligament extending from the styloid process of the skull to the ramus of the mandible. When the mouth is opened, the interarticular fibrocartilage which covers the condyle slides forward, leaving the surface of the glenoid cavity and advancing on to the eminentia articularis. If the joint capsule is very lax or there is a tear on its anterior surface, it is an easy matter for the muscles to pull the mandible farther forward and dislocate it. This displacement is aided by leverage action, the external pterygoid and temporal muscles furnishing the power to pull the bone forward, the fulcrum being supplied by the untorn posterior part of the capsule and the stylomaxillary ligament.

Pathology.—A very few dislocated temporomaxillary joints have been examined by dissection, because they are reduced and operation is not often indicated. The difficulty of reduction is explained by the changed lines of muscle and ligamentous pull after the luxation has occurred. The condyle is drawn forward up on to the beginning of the zygoma, but that impingement alone is not sufficient to obstruct reduction, as removal of the condyle may leave an unreduced joint. Rarely the interarticular cartilage may have been torn loose from the condyle and fill up the glenoid cavity, so that the mandible cannot be forced back into it. Stimson records a case of this kind cured by operation.[1] The action of the inelastic ligaments which remain untorn and the spasm of the stretched muscles of mastication act together to prevent the condyle from slipping back.

Symptoms and Diagnosis.—The mouth is held open, the lower jaw is held rigidly. When questioned, the patient can indicate that he felt the jerk of dislocation. The mouth cannot be closed in most cases, or if it is, the teeth of the lower jaw project forward beyond those of the upper and there is great pain in the joint. The patient cannot move the lower jaw; so chewing is impossible, and talking is very indistinct, and there is drooling. Pain is variable; sometimes it arises merely from the discomfort of the locked open position of the mouth; in other cases there is sharp pain at the joint, increased by the spastic muscular contractions. A hollow can be both felt and seen in front of the auditory meatus. The muscles attached to the jaw are tense, and there is an abnormal prominence below the zygoma. Efforts to close the mouth are painful, and although the surgeon may be able to open the mouth a little wider by pressing down on the chin, resistance against reduction is firm.

Luxation of only one of the temporomaxillary joints gives a modification of these symptoms. The jaw is displaced laterally, the chin

[1] **Fractures and Dislocation, Seventh Edition, p. 548.**

being directed toward the sound side, the mouth is not so widely opened, and the lips may be brought together. The facial asymmetry may not be striking, but the deformity within the mouth is visible at once.

Fracture of the jaw is differentiated by the presence of bleeding within the mouth and a disturbance of dental alignment. Fracture of the condyle may be difficult to differentiate; usually the deformity in fracture is loose and easily replaced, to recur immediately when support is removed. There is also crepitus and the condyle cannot be felt when the jaw is moved.

Prognosis.—The prognosis is good both in regard to reduction and function. Very few cases are irreducible, and the return of function is prompt. When the jaw is once dislocated, the possibility of recurrence is great, and habitual dislocation quickly develops. Ahrens[1] has recorded a rare complication and unusual instance of dislocation of the jaw. The patient was a seven-months-old nursling which was threatened with inanition from an acquired habitual luxation of the jaw. When first seen the dislocation was of fourteen days' duration. The child could not swallow well, as on its attempts to open the mouth in order to take the nipple its jaw luxated. The deformity was typical and easily reduced, but it recurred quickly, especially as the child cried loudly with hunger. This is the youngest case on record that I know of, and the cause was obscure. The first dislocation may have occurred from crying or from attempts to clean the mouth with swabs. Cure was effected by the giving of urethan to induce a long sleep with the mouth closed. After the awakening only one breast feeding was allowed in the next twenty-four hours, and the dislocation did not recur. Probably a laxness of the capsule was the only pathology present.

Treatment.—Manipulation is based on the retention of leverage power in the intact ligaments. The ligaments must be relaxed. The attendant accomplishes relaxation by pushing down on the chin to open the mouth a little farther, then by direct firm pressure on the teeth inside the mouth or the mandible on the outside, pushes the jaw gently down and back until it slips into place with a jerk. This procedure enables the bone to reënter the joint in the way of exit and is simple and gentle. A second method which is similar to that of direct traction in larger joints is performed by direct pressure downward and backward on the molar teeth by the surgeon's thumbs, while his hands grasp the jaw and raise the chin simultaneously. The pressure overcomes the resistance of the muscles and ligaments and forces the condyle back into position. For the practice of this method the thumbs of the operator must be well protected by being wrapped with a bandage or by a doubly-folded towel placed about them. The jaw jerks into place with much force, and unprotected skin always suffers between the teeth. As the reduction takes place, the thumb

[1] Monatschr. f. Kinderheilkunde, Berlin, xiii, No. 5, p. 230.

can be withdrawn laterally into the cheek cavities and so removed from the mouth. Unilateral cases need the same type of treatment, with more attention to lateral swinging of the jaw toward the affected joint as reduction takes place. Rarely a general anesthetic must be given to produce relaxation; then the same method of reduction is pursued. Spontaneous reduction occurs, especially in habitual dislocation, and some persons can dislocate the jaw forward and reduce it at will by muscular action.

After-treatment consists in eating of soft food for a few days so that chewing will be unnecessary. The patient is cautioned not to laugh or yawn and is advised to open the mouth but little. If there is tendency to easy recurrence, the jaw can be held for a week in a four-tailed or Barton bandage used in jaw fractures.

Operative treatment is applied to unreduced cases and to fresh cases which cannot be slipped into place even with the help of anesthesia. Several attempts at reduction should be made in bilateral luxation before operation is decided on.

Operative approach is made through a skin incision below the zygoma, the dissection being carried down to the mandible by splitting and retraction. The edge of the parotid gland is held back out of the way, and branches of the facial nerve are avoided. If the case has been of long standing or a fracture of the condyle has complicated it, Murphy's method of approach by means of a two-inch incision starting on the level of the zygoma and half an inch in front of and on a line with the external auditory meatus can be used.[1] This opening runs upward into the hairy scalp. It has the advantage of opening a field from which a flap of temporal fascia may be secured to swing into the joint, if the surgeon considers an arthroplasty necessary to avoid subsequent ankylosis. The scar is also partly covered by hair.

After exposure the reduction may be accomplished by leverage with a small periosteotome, or if the condyle is an insurmountable difficulty to reduction, it can be resected.

In 1899 McGraw described his operative method of reduction of long-standing dislocation.[2] His patient was a man thirty-three years old, who had suffered an apoplectic attack and fallen down. The lower jaw was dislocated forward, and the true condition was not recognized until five months afterward. Attempts to force reduction under anesthesia failed, and McGraw had made a steel hook which had space between the prongs and shaft just wide enough to permit passage over the jaw at the sigmoid fossa. A small incision, not an inch long, affords sufficient room to pass this hook over the bone through the split masseter muscle. Traction is made backward and downward on the condyles and an assistant pulls up on the chin. McGraw used the hook on one side, making traction for fifteen minutes, at the end of which he felt that the jaw was giving a little. The other side was opened and the reduction was accomplished by the

[1] Clinics, ii, 663. [2] Med. Record, 1899, lvi, 511.

hook traction. Immediately after reduction it was noted that the teeth still protruded slightly and that there was some prominence over the joint, but this displacement slowly subsided, and the jaw became normal in function and appearance after a few weeks. Complete immobilization for two weeks is necessary after operation. Other operated cases have been recorded by Brockway.[1] His case was of thirteen months' standing, and the condyles were pried into position through an incision. Dawbarn[2] cited two cases in both of which reduction was effected by partly dividing the masseter muscle. Mazzoni[3] successfully operated on a case which had remained irreducible for eight days. Both condyles were resected.

The after-treatment consists in the holding of the jaw in place for at least two weeks by a bandage or a light plaster-of-Paris dressing about the head, the patient subsisting on soft diet and not attempting to move the jaw. When arthroplasty is performed in connection with reduction, it is better to dress the mouth open by means of a wooden plug inserted between the teeth. This is worn for at least a month until the periarticular structures have become firm and the interposing flap between the joint surfaces has had an opportunity to take on new function.

Recurrent Forward Dislocation.—Recurrent forward dislocation may become very frequent, although the patient learns to be constantly on his guard against it and is able to reduce it himself. To effect a cure the attendant should try long immobilization; at least six weeks in a head bandage is necessary. If that fails, periarticular injections of iodine or alcohol may be used. The final recourse is open operation. If the interarticular cartilage is loosened, it may be stitched in place or removed entirely, this procedure followed by a capsulorrhaphy to tighten the relaxed anterior ligament.

Recurrent forward *subluxation* is a condition much like that of the snapping or trigger joint. In the act of masticating or talking the patient is conscious of the jaw slipping partly out of place, accompanied by a cracking noise heard loudly in the ear on the affected side. There may be a sensation of partial locking open of the jaw, which is momentary, and reduction is spontaneous. Rarely the patient has to take hold of the jaw, swing it a little laterally, and press it back into position. The condition is usually painless and may depend on a lax capsule or a loose interarticular cartilage. If repeated unpleasant recurrences make the condition unbearable, the injection treatment can be applied. Operation is seldom indicated.

Dislocation Backward.—Dislocation of the lower jaw backward is rare and is nearly always caused by direct violence of a blow on the chin. It may be unilateral or double, and two forms of displacement exist. In the first the jaw is displaced backward and held by the interposition of the displaced interarticular cartilage. The mouth is closed

[1] Johns Hopkins Hosp. Bull., May, 1890.
[2] New York Med. Jour. March 12, 1892.
[3] Gazz. Med. di Roma, 1877, No. 4.

tightly, the lower teeth failing to occlude with the upper. Reduction is easily accomplished by traction. The second type involves severe direct violence and may be accompanied by fractures of the condyle. The anterior wall of the external auditory canal is crushed in, and the mouth hangs open in a fixed position. The condyle is driven backward, and its prominence in the cheek is lost. There may be a bulging or a complete occlusion of the auditory canal and bleeding from the ear.

Müller[1] has reported a case of backward dislocation of the temporomaxillary joints with rupture of the bony auditory canals. The patient, a man twenty-two years old, fell off his horse, striking his face on the ground. There was hemorrhage from both ears, a deep cut in the lower lip and unconsciousness. He was unable to occlude the teeth, became deaf and could not talk. An irreducible bilateral ankylosis of the temporomaxillary joints was established. After a few months he suffered an attack of la grippe and was nearly asphyxiated by mucus which he could not expectorate. When he appeared for treatment he had a stupid look, his face was immovable and inexpressive; there was retraction of the lower part of the face and the labial folds and he talked as if he had a bulbar paralysis. The lower teeth were 10 mm. behind the upper and only 8 mm. of motion could be obtained when efforts were made to pry the jaws open. Into the canal of the left ear a speculum entered only 1 cm., and the anterior wall was found pushed against the posterior. Slight movements of the jaw were communicated to the anterior wall. In the right ear the same findings were present except that the canal admitted a fine probe.

Treatment was applied by means of Rochet's operation.[2] An incision was made beginning at the lobule of the ear along the posterior angle of the mandible. The masseter muscle and periosteum were reflected, a triangular piece was removed from the ramus after cutting it off from the body by a Gigli saw and a flap of soft parts was inserted between the bone ends. Müller operated on both sides, with an interval of ten days between operations. Five months later there was good motion in the jaw, the masseter had become reëducated, but the lower teeth were still retracted so that the patient could not use the incisors and canines.

A case of double congenital ankylosis in a five-year-old child was reported by Huguier, who also used Rochet's operation by a trapezoidal osteotomy and interposition of a flap of muscle. The best results that one can hope to obtain in bilateral ankylosis is a movement of lowering and raising the jaw. Lateral movements of propulsion and circumduction are gone forever because at the point of bone resection the insertion of the external pterygoid muscles are cut off. In a unilateral ankylosis one might look for a perfect result by the method of resection of the condyle or osteotomy of the ascending ramus, because

[1] Paris Chir., 1911, iii, 832.
[2] VIII Congress, franc. de chir., 1894 and 1896; Arch. provinc. de Chir.

one external pterygoid muscle is enough to give propulsion and lateral movements to the jaw.

Upward Dislocation.—Upward dislocation is extremely rare and is caused by direct violence on the chin which drives the jaw upward through the glenoid cavity of the skull. The condition is similar to the central dislocation of the femoral head into the pelvis through the shattered acetabulum. The skull fracture constitutes the real injury, the displaced position of the jaw is unilateral, and the dangers and complications are those of skull fracture and damage of the cranial contents. Hemorrhage and brain abscess have been recorded. The mouth is fixed slightly open, swallowing and mastication are painful, and the ear on the affected side may bleed. Reduction is performed by traction downward on the jaw.

Inward and Outward Dislocation.—Inward and outward dislocations are also rare. Inward dislocation cannot take place without fracture of some part of the jaw and possibly of the skull bones about the temporomaxillary joint. Outward dislocation occurs under conditions of fracture and direct violence. The condyle is swung out over the zygoma while the coronoid process hooks under the zygomatic arch. Reduction is by traction and direct pressure downward on the jaw fragment to unhook the condyle, which is then pressed back into place. The fracture must then be treated.

CHAPTER X.

FRACTURES AND DISLOCATIONS OF THE VERTEBRÆ.

THE thirty-three vertebræ composing the spinal column consist of the true or movable vertebræ, and the false, or fixed vertebræ formed by union of segments in the sacrum and coccyx. Fracture is of greater interest in the true vertebræ on account of their more exposed position and the fact that the nervous tissues which they guard are of greater importance. The normal curves of the spinal column, the cervical, convex forward extending to the second thoracic vertebræ; the thoracic, concave forward from this point to the twelfth dorsal; and the lumbar, convex anteriorly from the last dorsal to the sacrovertebral articulation, furnish a pleasing variation in contour, permit greater freedom of action in spinal, head, and limb movements and add to the strength and ability to withstand shocks. There is usually present a lateral curvature to the right, probably caused by increased muscular use of that side in right-handed persons.

The posterior surface of the column is formed by a line of spinous processes which appear subcutaneously and are of interest clinically as landmarks, and which are the palpable portions of the vertebral column. Palpation of the pharyngeal wall through the mouth permits examination of the anterior surfaces of the bodies of the first five cervical vertebræ.

The cervical spines, with the exception of the long seventh cervical, are short and bifid at their extremities and are placed horizontally. The thoracic spines in the upper part are directed obliquely downward, near the midthoracic region they become nearly vertical, and the lower thoracic and lumbar spines approach the horizontal again. Rarely a spinous process deviates from the customary position in the median line and may offer confusing findings in cases of suspected spinal fracture.

The column is elastic because it is composed of so many points bound together by the complexity of ligaments, and because of the close interlocking of the individual vertebræ and the presence of the shock-absorbing intervertebral cartilages in each joint. Further safety is provided for the bony column by the curves described, which break it up into three separate columns, each one of which demands greater force to produce bending than a longer curve of equal breadth and material. Bending, therefore, under ordinary circumstances, must occur before breaking. Position, function to support the trunk and head, and the many movements to which it is subjected expose the column to mechanical injuries in spite of its construction and

muscular protection. Sprains, caused by exaggeration of any normal movements, with laceration of the ligaments are not severe, because violence of sufficient force to tear the ligaments widely would rather cause fracture or dislocation. For this reason fractures and dislocations of the vertebræ very frequently accompany each other, and their pathology is closely intermingled, so that fracture-dislocation might be a better general term to apply.

Direct or indirect violence and, rarely, muscular action, are the cause of fractures of the spinal column, and although the injury is of importance in its bearing on the supporting function of the head and trunk, the injury of the nervous content is of more interest. Fractures caused by indirect violence, or an exaggeration of the normal curves, are more common. In this type the arches are separated and the bodies are compressed, while in fractures arising from direct violence the reverse is true. In both the medullary canal is the least likely to be subjected to violence. Displacement is nearly always that of the upper fragment driven forward on the lower when indirect violence is the cause, so that the cord is compressed between the arch of the upper and the body of the lower vertebra.

Occurrence.—In the collection of 11,302 fractures at the Cook County Hospital the vertebræ were broken in 138 instances, or 1.2 per cent. Corwin's collection of 11,035 fractures at the Minnequa Hospital[1] gave 242 spine fractures, this high proportion arising from the fact that most of the patients were miners, a class exposed to this type of injury. Stimson's statistics gave 0.5 per cent. of the total number as fractures of the vertebræ. Cervical fractures are the most common, dorsal fractures coming next, and lumbar last in order. Of the 138 fractures mentioned above, 47 were specified as cervical. In 1914 at the Cook County Hospital there were 11 fractures of the vertebræ, 6 of which were cervical, 2 of the 4th, 1 of the 5th, 2 of the 6th, and 1 of the 7th. There were two 1st lumbar fractures, both of which recovered. Cervical cases have a much higher mortality than any others; 1 of the 6 above lived three months. Of these 11 cases, 8 died, 3 recovered; 4 laminectomies were done, all with fatal results. Two or more vertebræ may be broken simultaneously, especially in the cervical region, rarely in the lumbar (see Figs. 79 and 80). Children because of more elastic spines, and the aged, who are not exposed to severe injuries, rarely have these fractures, and most of them occur in male adults, teamsters, structural workers, miners, etc.

Fractures of the spinous and transverse processes are now found to be more frequent than was formerly believed, because of more careful study of spinal injuries by means of the Roentgen rays. The body of the vertebra is most frequently concerned, particularly in the dorsal and lumbar regions.

Pathology.—Fracture of the vertebral body may be a crack across it in any direction completely through its width, or a fissure ending in

[1] Jour. Am. Med. Assn., lvii, 1351.

the cancellous tissue. The vertebræ, like the os calcis, are built for weight-bearing and shock absorption and are made up of cancellous

FIG. 79.—Fracture of the spinous processes of the third and sixth cervical.

bone with a narrow cortical shell. If a fissured fracture is complete, the line may run obliquely from above downward and forward, or vertically, or even horizontally, with no displacement or separation of fragments. A split-off wedge may be displaced forward, a usual

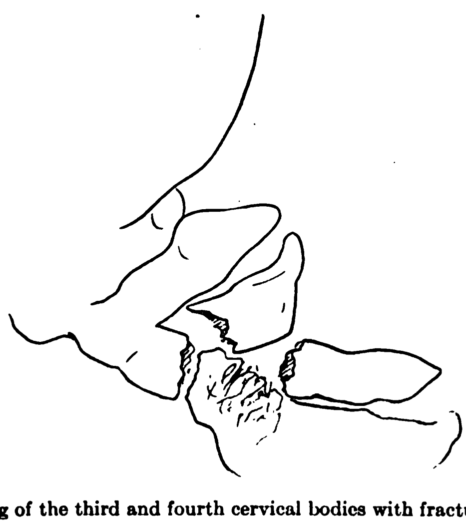


FIG. 80.—Crushing of the third and fourth cervical bodies with fracture of their spinous processes.

condition (Figs. 81, 82, and 83), or the body may be crushed or comminuted into several pieces. The transverse and oblique fractures

occur in the upper part of the body, and the upper fragment is displaced forward and downward with the portion of the spine above,

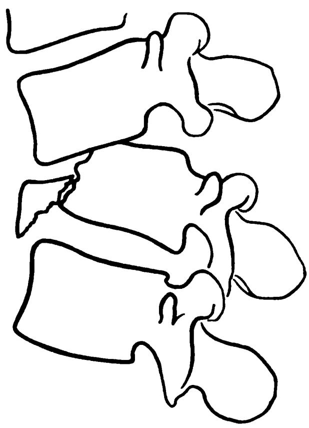


Fig. 81.—Split-off wedge from the body of the lower thoracic vertebra with an oblique plane of separation.

the lower part remaining in its normal position in connection with the bodies below. This causes an angulation in the bony spine with a sharp point projecting backward like a gibbus, the external deformity being enhanced by the separation of the spinous process of the

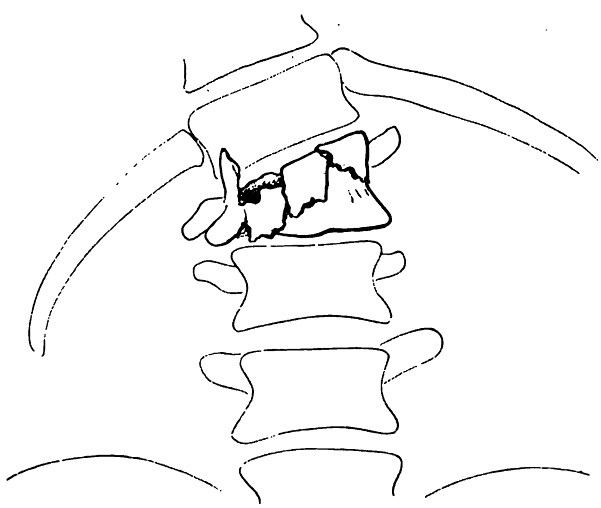


Fig. 82.—Crushing fracture of the body of the lumbar vertebra.

broken vertebra and the intact one above it. Lateral rotation or simple lateral displacement may be a complication (Fig. 84). A narrow

range of rotation can be present without additional bony injury, especially if the fracture of the body is transverse. More extensive

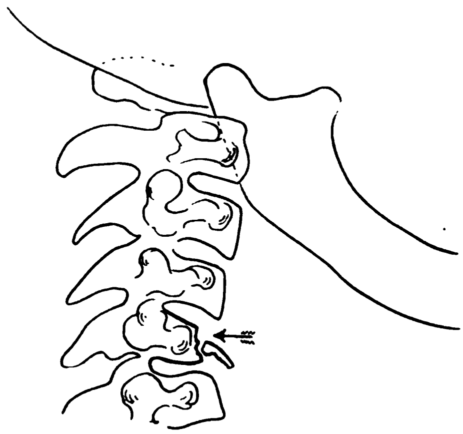


Fig. 83.—Fracture of the body of the sixth cervical with forward displacement of a fragment.

rotation or distinct lateral angulation can only be accomplished by accompanying fracture or dislocation of the articular processes.

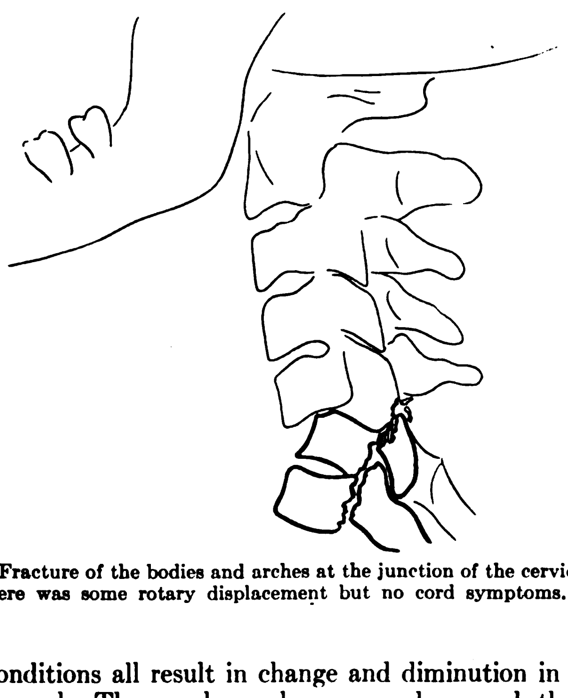


Fig. 84.—Fracture of the bodies and arches at the junction of the cervical and dorsal regions. There was some rotary displacement but no cord symptoms. (Dr. C. B. Davis.)

These conditions all result in change and diminution in size of the medullary canal. The canal may be narrowed so much that the cord

is compressed or even severed by the edge of the body below and the arches above, or in rotation or lateral displacement the canal may be narrowed in a lateral diameter so that similar cord compression results.

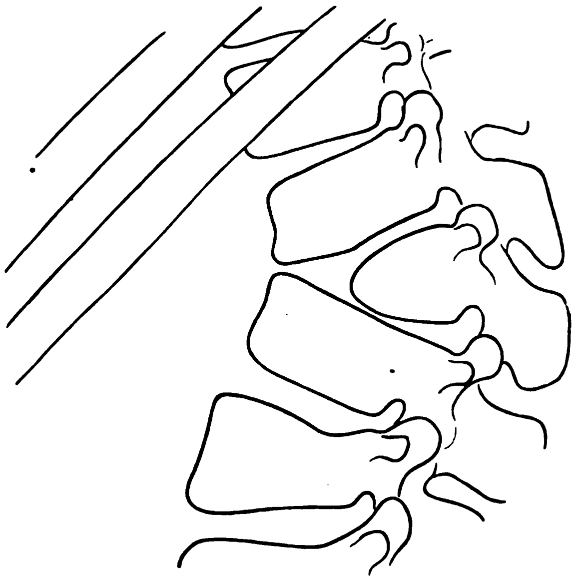


FIG. 85.—Compression fracture of the lumbar body of nineteen years' standing, cord symptoms first appearing at that time.. (Potter.)

Compression of one or more vertebral bodies from violence, especially in a slightly flexed position, causes crushing of the cancellous bone and

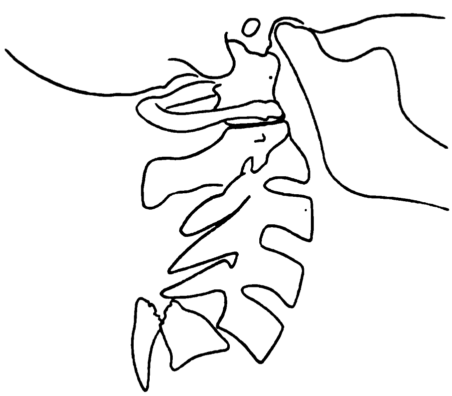


FIG. 86.—Fracture dislocation of the lower cervical region.

it becomes denser. This may effect the whole body, or the upper and lower anterior edges, so that the normal quadrilateral appearance in roentgenogram profile becomes wedge-shaped. This is very evident

in old compression fractures which may have existed for years without cord symptoms or changes, the bone wearing down until the injured body is triangular in outline (see Fig. 85).

Although the bodies are constructed to bear these sudden applications of force, the posterior portions of the vertebræ are so firmly locked and fastened by the ligaments that in flexed positions they maintain their slightly elastic support and the bodies are forced to give by compression. The cancellous tissue may be forced out laterally or backward into the medullary canal, and the intervertebral cartilages may come to lie in contact. Impaction of one part of the body into another, as in the extremities of long bones, or the femoral neck, may also cause this body compression. The intervertebral cartilage may

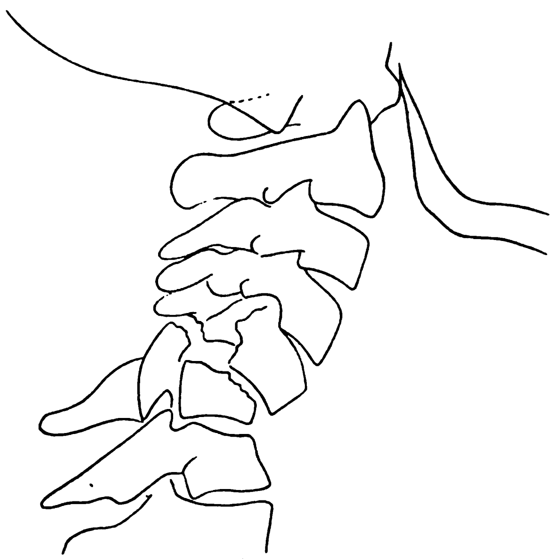


FIG. 87.—Fracture dislocation of cervical region. Note the forward displacement of the bodies of the upper vertebræ.

be forced out, instead of the bone being crushed, and they may pull out with them shells or splinters of bone. Associated injuries, fractures of the transverse processes of the vertebræ or fissures in neighboring bodies are found.

Later changes consisting of callus formation and extrusion at the intervertebral foramina or into the medullary canal may cause pressure symptoms and signs through change in the angulation of the cord or the decrease in the foraminal aperture, and demand treatment for relief of pain and paralyses.

The *arches* of the vertebræ are broken in connection with fracture of other parts, rarely alone, except in gunshots (Figs. 88 and 89). The most frequently involved region is the cervical, because the individual vertebræ are broad and are lacking in strong supporting spinous and

transverse processes. This complication is not present in more than 10 per cent. of dorsal and lumbar fractures. Loosened pieces, broken off

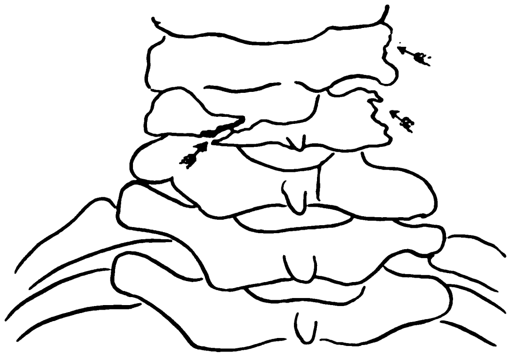


Fig. 88.—Fracture of the arch of cervical vertebra.

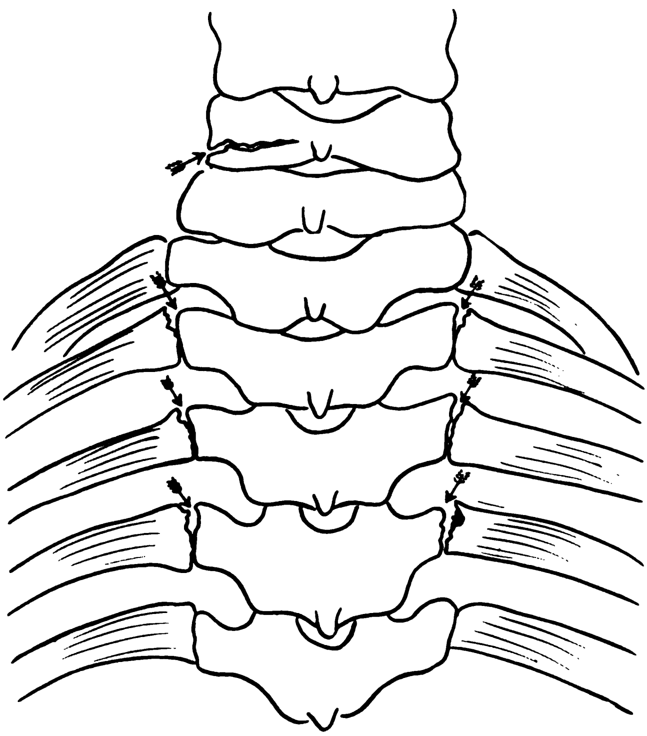


Fig. 89.—Fracture of arch of cervical vertebra with multiple separation of the ribs at their vertebral attachments.

by direct violence, may be driven into the medullary cavity and cause a severance of the cord and death. A spinal injury with bladder and

rectal paralysis arising from splinter of bone driven into the cord is recorded by Borchard.[1]

Fractures of the *transverse* and *articular processes* occur under two conditions. In the upper portion of the spine they usually are found in conjunction with fracture or dislocation of other parts of the vertebræ. In the lower spine, especially the lumbar region, they are caused frequently by muscular action (see Fig. 90). Fractures of the ribs close to the spine in the dorsal region may involve the articulation with the transverse processes and *vice versa*. Dislocations of the cervical vertebra often are the cause of fractures of the articular process, but if this process is first fractured, dislocation may easily follow.

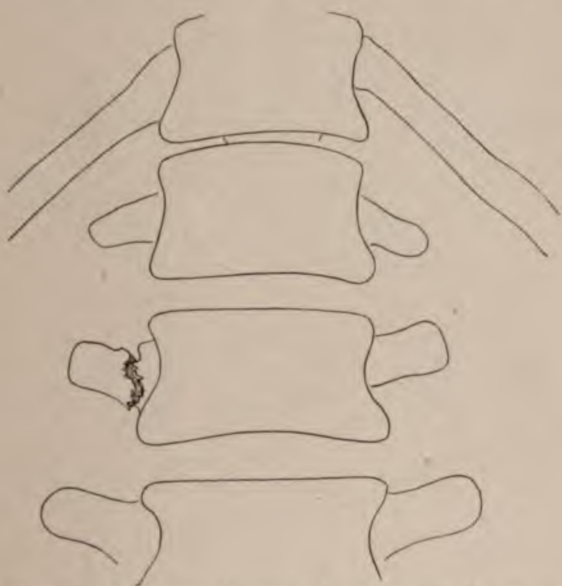


FIG. 90.—Fracture of the transverse process of the second lumbar vertebra by muscular action.

Hoffman[2] reported an instance of fracture of five of the transverse processes of the lumbar region following muscular exertion. He states that there are 9 cases on record, the 1st and 2d lumbar processes fractured in four instances, the 3d in six, and the 4th and 5th in two. The case illustrated in Fig. 91 has not been reported before and shows the widest separation of fragments of any case on record. These fractures are caused by forcible contraction of the psoas and quadratus lumborum and longissimus dorsi muscles. That the processes do not fracture more frequently is because severe traction strains are nearly always met in an upright position, in which the strain is sustained by the broadest diameter of the process. Fracture

[1] Archiv f. Klin. Chir., cv, No. 2.
[2] Med. Klin., Berlin, August, 1914, x, No. 32.

occurs during the lifting of heavy weights, when the individual is in a flexed forward position. A case in a fifty-year-old man was reported by Lange.[1] He strained his back lifting a heavy tray of samples out of a trunk and experienced great pain when stooping over, walking fast, or riding on cars. There was a spot of acute tenderness about the size of a dollar just to the left of the last lumbar vertebra, and although the patient was well developed and used to lifting feats, the pain persisted and resisted all treatment. Roentgenogram betrayed

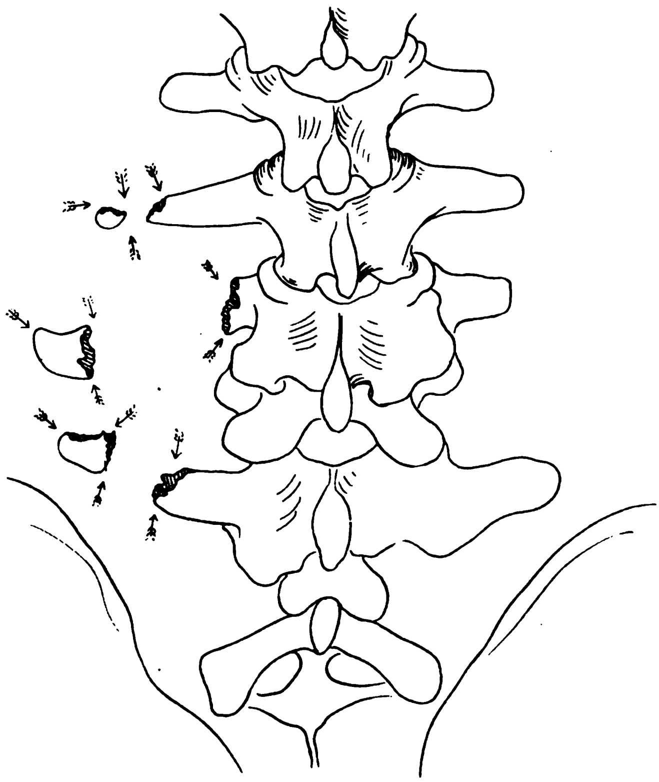


FIG. 91.—Multiple fractures of the transverse processes of the lumbar vertebræ with wide separation of fragments. These cases are frequently diagnosed as sprained backs.

a fracture of the left transverse process of the 5th lumbar (Fig. 92), tilted up at an angle as though drawn there by muscle (erector spinæ) and some union to the vertebra seemed present.

A second case in a thirty-five-year-old man followed a severe blow on the back by an automobile crank handle. There was right lumbar rigidity and pain, the Roentgen picture showing an upward displacement of the transverse process of the 1st lumbar and no other injury.

[1] New York Med. Jour., October, 1906, p. 691.

Ehrlich[1] reported 1 case, and Hoglund[2] reported 7 cases met with in six years, all verified by roentgenogram. Diagnosis is of importance in these cases from the prognostic standpoint of injuries called sprained backs.

An early symptom is abdominal pain caused by the pressure of fragments or of the hematoma on the nerve trunks. This may also cause reflex rigidity of the abdominal wall, or the pressure or stretching of the psoas may cause pain simulating appendicitis. Tauton[3] reported a diagnostic sign of localized pain arising from lifting of the

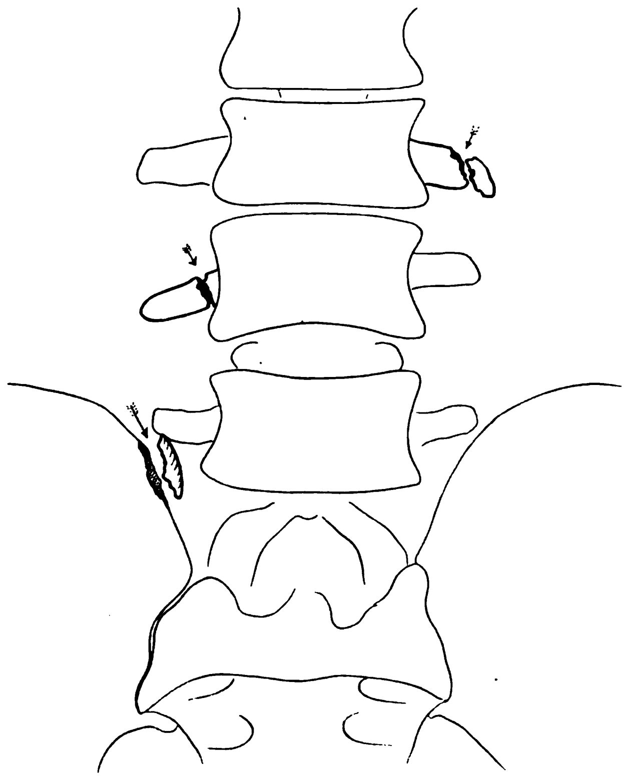


FIG. 92.—Fracture of transverse process on opposite sides of the lumbar vertebræ. There is also a fragment of bone broken off the iliac crest.

leg when the patient is lying on the back. Other symptoms are local tenderness in the lateral lumbar region on pressure and painful bending. These may either all subside or else lead to constant pain and a neurotic condition, the relief of which can only be reached by excision of the fragments. Many of these cases have undoubtedly been called lumbago, osteo-arthritis, traumatic neuroses, or railroad spine, before the use of the Roentgen rays.

[1] Deutsch. Ztschr. f. Chir., xcii, 413.
[2] Ibid., cxvi, 321.
[3] Rev. de Chir., xlii, 1101.

Fracture of the *spinous processes* constitutes more than one-half of the fractures of the cervical vertebræ according to Scudder. Direct violence to the spines is the most frequent cause and is in many instances followed or accompanied by hyperflexion with one or the other end of the spine fixed, the opposite one mobile. The jackknife mechanism caused by men on wagons driving under a bridge or doorway, is frequently the cause (see Fig. 93). Muscular action as in sudden hyperflexion sometimes accompanied by rotation also is a cause. In the dorsal region fracture of the transverse process or other part of the ver ebra frequently accompanies. The broken spine may be displaced downward or laterally and downward, the soft parts in most cases giving little evidence of the trauma. Scott[1] reports a case caused by the trauma of an iron pipe thirty inches long, falling from a height onto a man's back. Some of these injuries are open fractures, most of them closed. Unless the loose spine can be grasped and moved, or crepitus obtained, diagnosis is difficult and depends on a good lateral roentgenogram. In the stronger lower dorsal and lum-

FIG. 93.—The jackknife mechanism of spinal fracture seen when teamsters try to drive under a doorway not bigh enough to allow passage. Adapted from Cotton.

bar vertebræ, the site of fracture may be near the tip of the process; in the dorsal and cervical regions the line is generally nearer the mass of the vertebra.

Cord hemorrhage after spinal injury, may be extradural or intradural as in the skull. The cord is hung in the spinal column in its watery bed of cerebrospinal fluid with ample space around it. Extradural hemorrhage from the plexus of veins may spread quickly and widely up and down the canal, but I believe is rarely responsible for pressure symptoms. There may be a temporary increase in intraspinal and intracranial pressure, but severe hemorrhage without fracture, or without actual injury of the cord itself is rare, although the condition of cord contusion or concussion, like that affecting the brain, is accepted. The rapid circulation and absorption of the spinal fluid precludes great pressure from hemorrhage. Rarely hemorrhage is very free, and spinal puncture will bring forth almost pure blood.

Intradural hemorrhage or *hematomyelia* is more serious and is

[1] Railway Surg. Jour., 1915, p. 180.

probably caused by a stretching of the cord in hyperflexion, or extension, or from direct violence following bone injury. This hemorrhage is usually found in the cervical and upper dorsal regions, in the gray matter, spreading upward and downward for many segments and may be accompanied by capillary hemorrhages in the white matter. Anatomically the reader must recall that the motor or anterior nerve roots arise from the anterior horn of the cord, and are the axones of ganglionic cells in that horn. These connect above or within the central nervous system, with the cortex, and below, or externally, with the muscles in the periphery. The medullary sheath is supplied to the axone as it passes out from the anterior cord; the neurilemma is not supplied, however, until the axone leaves the spinal fissure.

The posterior or sensory nerve roots are composed of efferent axones arising in the ganglionic cells of the posterior root ganglia, which are located for the most part within the intervertebral foramina. Axones also extend from these ganglionic cells to the periphery and the sensory neurone is made up of afferent axones, to the periphery, and efferent axones, to the cord, together with the ganglionic cell bodies. These sensory axones, except that portion passing within the spinal cord, have a neurilemma. Neurilemmatous axones, if united under favorable conditions after division, are capable of regeneration; that is, the spinal nerves and the cauda equina will unite, but the cord does not. (See cases of supposed regeneration of cord to follow.)

Scar tissue fills in after destruction of the cord, but this is functionless. Nash[1] reported a case of spinal fracture with paraplegia below the lumbar region. The spinal canal, exposed eight months later, between the 8th and 11th dorsal vertebræ, revealed only fibrous strands following complete disappearance of the cord. Taylor[2] cites a case of a female trapeze performer who fell and fractured the 6th cervical segment. Immediate laminectomy was done, but she died in three days, and the subsequent examination of the cord showed a widely extending, tubular hemorrhage down the cord substance. He believed that the operation helped toward the fatal result, because it added to the shock, which is greater in the cervical region than in decompression of the brain, on account of the proximity of the medulla. The extravasation of blood in the cord may be so great that temporary hemiplegia results, clearing up later either completely or in part. The extravasated blood in causing distention may also cause so much pressure that neighboring axis-cylinders are completely destroyed and are replaced by granulation and cicatricial tissue, a cyst or cavity remaining, which contains the modified serum. If the surrounding nerve elements are not destroyed, but are merely under such pressure that function is suspended, it is important to diagnose the condition and operate to relieve the tension. The hematomyelia may affect one side of the cord alone. Such a case was reported by Tilney and

[1] Australas. Med. Gaz., xxxv, 314.
[2] Boston Med. and Surg. Jour., clxvii, No. 20, 675.

Nichols,[1] following fracture of the 6th cervical in a diving accident. The man (twenty-eight years old) had an immediate hemiplegia of the right arm and leg with awkwardness of movements on the left side and no loss of consciousness. There were no permanent eye, bladder, or rectal symptoms, and the final condition was a flaccid paralysis of the right upper extremity, spastic paralysis of the right lower extremity, increase of the right tendon reflexes and loss of the right abdominal epigastric and cremasteric reflexes. There was also a positive Babinsky and ankle-clonus on the right side. The whole left side was normal.

Some years ago at the Cook County Hospital there was a patient who had been slugged in an alley and rendered unconscious. After a short time he awoke and managed to drag himself home, a distance of two squares. He never had a complete paralysis of the limbs and after two weeks began to walk. In a few months he gradually developed a weakness and disassociation in the limbs and an anesthesia to heat and pain, a typical syringomyelia. A Roentgen picture, taken six months after the accident, showed a fracture of the 7th cervical vertebra. He had probably had a central hematomyelia. One might be tempted to conclude that in similar fractures or spinal injury, if the pain and heat senses are disturbed early, if ever so slightly, there is indication of central hematomyelia with distention of the central canal, and the probability of operation would be very carefully weighed. On the other hand, if the tactile sense was involved as well as the pain and temperature sense, one would feel sure that the hemorrhage was not confined solely to the central canal, but involved the cord more extensively, or the disturbance was possibly caused by pressure from without, and operation for clot or bone pressure would be indicated. Allen, on a basis somewhat similar to this, advocated early operation with a delicate longitudinal opening in the dura to relieve cord pressure within by drainage. (See Treatment.) Frazier[2] records a case treated by this method. There was a mid-dorsal fracture which was opened within five hours from the time of injury, a gush of fluid appearing when the contused site was cut into. After four months there was some return of sensation, none of muscular control. On the whole, results are disappointing; on account of the character of these injuries, one surgeon rarely has an extensive experience in them and cannot adopt a well-planned line of treatment. A few months ago I had a fatal case of fracture of the 7th cervical vertebra. No operation was performed. At the autopsy the cord was carefully removed. It must be understood that in removing the spinal cord it should not be cut into or pressed upon, nor can it be bent or flexed. Any of these conditions will cause changes which are apparent in a microscopic section and lead to false deductions pathologically. The cord in question showed practically no gross change on the dural surface. Delicate

[1] New York Neurol. Soc., October 6, 1914, abstracted Jour. Am. Med. Assn., November 28, 1914.
[2] Surg., Gynec. and Obst., March, 1913.

palpation by the index finger run along its continuity disclosed an area of depression or softening at a site which corresponded to the bone fracture level. When the dura and pia were opened there was found a hemorrhagic mass beneath, which extended two or three segments downward and one upward. Section of this cord verified this hemorrhage and destruction (see Figs. 94, 95, and 96). Undoubtedly whatever damage is done to the nervous elements of the cord is done immediately at the time of injury, and no line of treatment will affect the permanent destruction. Pressure from bone, or fluid from

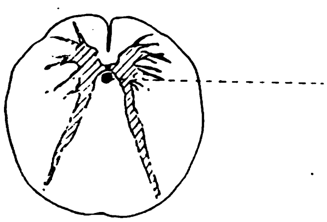


Fig. 94

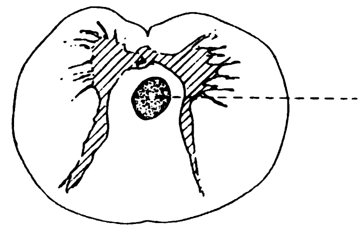


Fig. 95

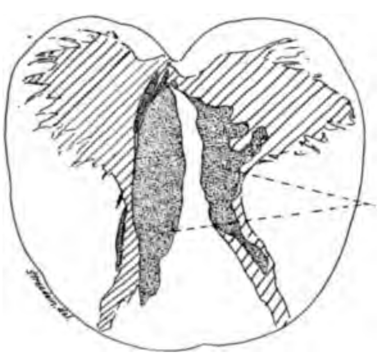


Fig. 96

Figs. 94, 95, and 96.—Schematic drawings made from sections of the spinal cord in a fatal case of fracture of the 6th cervical vertebra. At the lesion site the removed cord showed no evidence of injury, a palpable depression was found there by the finger. Fig. 94 shows hemorrhage in the central canal above the cord compression. Figs. 95 and 96 are in the upper and lower dorsal regions, showing the downward extent of the hemorrhage.

hemorrhage or edema, is amenable to treatment. Cases which are seen weeks or months after injury with nerve root or cord symptoms of pain and paresis, present pathology based on displacement of the cord caused by callus formation, or a wearing down of a broken body until the cord ultimately comes within pressure limits. Cysts of blood serum may also cause late pressure effects. In these cases the axis-cylinders have not been destroyed in the injury, and relief can be promised through removal of bone or cyst pressure to allow a resumption of normal function by the nervous elements.

Symptoms and Diagnosis.—Symptoms of fracture of the vertebræ may be entirely lacking, or at least unrecognized as coming from the spine. The evidence common to gross lesions, involving the bony parts and the cord also, are those of paralysis and loss of sensation of all parts below the segment supplied by nerves which take origin in the injured area. It is therefore necessary to have general knowledge of the points in the cord at which each nerve originates, and the fact must be borne in mind that many spinal nerves originate at a point higher in the cord than their emergence from the bony column.

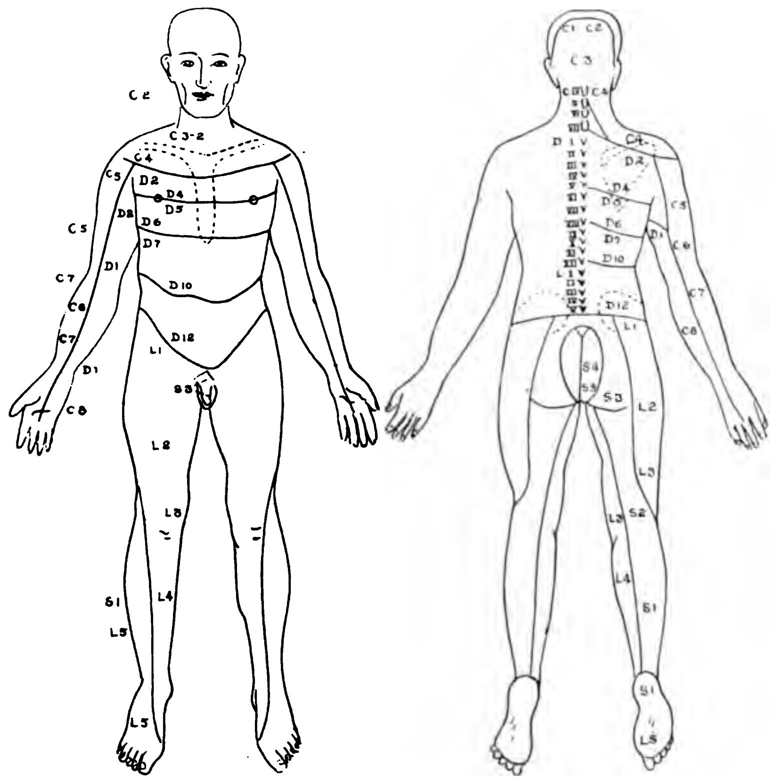


Fig. 97.—Emergence and peripheral distribution of spinal cord segments. (Adapted from Scudder.)

From their point of origin these nerves pass downward within the vertebral canal for some distance; the anatomical finding is that the lower the nerve's origin, the longer its course within the column (see Fig. 97). For practical use the cord may be divided into four parts to aid the memory: (1) Between the occiput and the spine of the 6th cervical vertebra the 8th cervical nerves take their origin in the cord. (2) Between the 6th cervical spine and the 10th dorsal spine arise the twelve dorsal nerves. (3) At the level of the 11th and 12th dorsal spines the five lumbar nerves originate and (4) the five sacral nerves arise at the cord level corresponding to the 1st lumbar spine.

General symptoms found in fractures elsewhere in the body are recognized in the spine after trauma. There is shock of varying degree, pain and tenderness to manipulation over the site of injury, crepitus in some instances which may be felt by the patient when he is moved, and abnormal mobility and deformity in the back. There may also be swelling, which masks the deformity of an angular backward displacement, like a kyphotic gibbus. If dislocation or lateral displacement is present, the deformity is more irregular in appearance and may not be noticeable in any degree. A case admitted to the Cook County Hospital with a rather high, remittent fever and great prostration was considered a walking typhoid. After several days, when being given a bath, the patient was rolled over in bed, and death followed in a few minutes. Autopsy showed fracture of the 4th cervical vertebra; the sudden movement had caused fatal cord pressure. There had been no external spine deformity. A similar fatal case has been mentioned by Pickard.[1] His patient injured his arm and also had some pain in the neck which was supposedly due to a wrench. After the arm was dressed the patient sat up in bed asking for a drink, to receive which he turned his head and collapsed.

Trauma resulting in temporary separation of vertebræ with immediate reposition, may cause hemorrhage from the venous plexus surrounding the cord and produce paralysis from pressure. Rough handling by those who do not appreciate the gravity of the injury, or by overzealous assistants in ambulance and hospital service, may increase displacements and cause more extensive injury and increased paralysis.

A gradual *increase* in the extent of the paralysis indicates pressure extending from extradural hemorrhage in progress, or from hematomyelia. An ascending myelitis from nutritional or circulatory disturbance produces similar results. As described in the pathology of hematomyelia, the hemorrhage may be unilateral. Usually the first symptoms are total paraplegia, although rarely hemiplegia is found. If the gray column on one side alone is affected, the nerve cells taking origin from that area are destroyed and the condition improves, so that in cervical hematomyelia the paralysis of limbs and sphincters may be recovered from, and one arm may remain useless. There is a loss of heat and pain sensation in the limb, but no loss of tactile sense.

Incomplete transverse crushing or damage of the cord results in irregular paraplegia and an irregular loss of pain, heat, and tactile sensation, part of which may be regained. The side affected most becomes spastic later, with exaggerated tendon reflexes. Complete transverse lesion gives complete permanent sensory and motor paralysis below the lesion. Different observers assert that in early stages following spinal injury it is impossible to say whether the crushing is total or not, and indications for operation (which see) may be overlooked.

[1] Railway Surg. Jour., 1914, p. 364.

The sensory and motor paralysis extends from the peripheral distribution of nerves taking their origin at the level of the lesion. At first all reflexes and motion may be lost; later these return and become increased with spastic contractions. If the lesion is high enough to involve the abdominal muscles and the nervous control of the bladder and rectum, there is retention of urine and feces with abdominal distention. This is caused not so much by lack of sphincter control as it is by loss of muscular tone in the bladder and bowel walls. If the catheter is not used, the bladder distends until a point of overflow is reached, and the urine begins to dribble away from an *incontinence of retention*. The bowels may follow the same course, usually at a much later period. These distended bladders are much like those in the terminal stages of a chronic prostatic hypertrophy, inasmuch as they are lacking in muscular tone, and catheterization to relieve distention will not restore this tone, and an infection which rapidly spreads up the urinary tract surely follows. Temporary suppression of urine may be due to the abolition of reflexes after concussion of the cord, and sphincteric and muscular control may return. Hematuria from simultaneous kidney injury has been observed.

Respiratory symptoms in high lesions concern the muscular action of the chest and abdominal muscles, or the diaphragm. Breathing may be continued by the diaphragm from the phrenic innervation when the chest muscles are paralyzed. Hypostatic congestion and pneumonia are frequent sequelæ. Pressure sores over the sacrum, trochanter, or buttocks appear very early. If the patient is not kept clean and dry, or is allowed to lie in one position too long, these may be evident within eighteen to twenty-four hours as red spots the size of the palm. Within a few days the skin sloughs, and a crater-like ulcer appears which is extremely difficult to control and may hasten death from septic absorption.

Priapism is found in nearly half the cases of cervical or upper dorsal fractures and practically never in lesions below the 1st lumbar. This is not a true erection, but rather a uniform, flaccid turgescence of the penis, which is not bothersome and generally becomes relaxed within a week or ten days, especially if urinary incontinence is well established. Ejaculations are rare. In many cases of hanging, with fracture of the upper cervical vertebræ, ejaculations are found after the body is cut down.

The evidence furnished by roentgenograms is of the greatest value in determining indications for treatment and the presence of bone fragments pressing on the cord. It should be obtained immediately, when possible, with the avoidance of all jars and movements of the spine which might exaggerate the existing conditions. Stereoscopic pictures are the best. Lumbar puncture, well below the site of lesion in most cases, which should be done with all aseptic precautions, is also an aid in diagnosis. If the spinal fluid is under increased tension, it demonstrates that there may be contusion or edema of the cord, or possibly hematomyelia when it is clear. If blood-stained, the

presence of blood in the dural sac is proved; and if the fluid is nearly all blood, alarming hemorrhage may be robbed of its pressure effects by operative interference. As in skull injuries, the spinal puncture may have a therapeutic effect of value.

FRACTURES OF THE CERVICAL VERTEBRÆ.

The most important are the injuries of the atlas and axis because of their proximity to the medulla oblongata and their position above the roots of the phrenic and other nerves governing respiration. Fracture dislocations often occur together, although either one or the other may occur alone (Fig. 98). Partial subluxation laterally is the

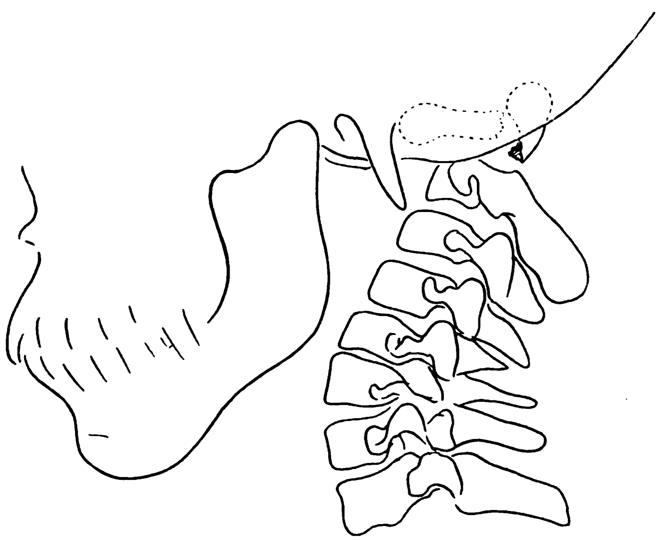


FIG. 98.—Lateral view of fracture of the axis near the base of the odontoid process.

most frequent injury of the atlas. Fracture of the odontoid process with lateral dislocation of the atlas are the next most commonly reported. Injuries of the atlas alone are rare.

Symptoms.—The symptoms depend on the displacement, and if there is none, life may be spared, but most cases die at once. Slight asymmetrical positions of the head, accompanied by neck stiffness and occipital neuralgia, with muscular rigidity and resistance to all motion, are the usual findings. Death follows later in cases with small displacement or in fracture of the odontoid process, when a sudden change in position causes the head to slip forward and crush or compress the cord. A secondary myelitis from the primary injury, the abnormal position or callus pressure pursuing a long course, may ultimately cause death from involvement of the medulla. Slight

displacements are considered common by Walton.[1] The physical signs as given by Mixter and Osgood[2] are: inspection reveals some unusual displacement on account of the asymmetrical position of the head. By palpation, the full line of spinous processes and their relative anteroposterior position is determined, and if the spine of the axis is abnormally prominent, a fracture of the odontoid is probable. In a normal neck the transverse process of the atlas can be palpated about half-way between the angle of the jaw and the mastoid. If there is rotatory displacement there will be two abnormal prominences, first from the forward displacement of the dislocated mass of the atlas and the other on the opposite side of the neck, lower down, which is the portion of the axis made more prominent by the slipping back of the atlas. The finger examining in the mouth may feel displacement along the pharyngeal wall.

In the unilateral type, the displacement is rotatory; the atlas slips forward on the side which gives way and either impinges on the articular process below or rests in the intervertebral notch. This does not cause cord compression or death, and these lesions can be reduced by manipulation after long standing. The mechanism of these subluxations is probably that given by Corner.[3] Free movements of the head demand that the ligaments at the occiput and spine shall be loose so that the head is held by muscular action alone. If it chances that the supporting muscular action is absent, any blow received on the neck has a "flying start" to produce dislocation or its complicating fracture. The integrity of the odontoid process is the most important point to determine from the standpoint of prognosis and treatment. This can be ascertained by a roentgenogram taken through the open mouth if the position of the head permits. In Corner's collection of 20 cases the odontoid was broken in 6 out of 8 instances which were fatal and in only 1 out of 10 which survived. But 2 of the fatal cases followed the accident immediately; some survived many years.

Van Assen[4] collected 19 cases of injury to the atlas, most of which were associated with other vertebræ, and 12 cases of injury to the axis, 9 of which were fractures of the odontoid process. Other cases of fracture of the odontoid have since been reported by Kiliani,[5] one of the tip of the process; by Wilson,[6] one in which final displacement was caused by an osteopath; and by Lambotte, one in which the patient, a woman, caused the condition by a sudden movement of her head while sewing, with death a year later. Elliott and Sachs[7] reported a case in a fifty-year-old man who fell when eighteen years of age, landing on the back of his neck. He was in bed for six months. For one year he could not move his head, and many years later, after being struck on the shoulder, he developed some weakness but worked

[1] Boston Med. and Surg. Jour., 1903.
[2] Ann. Surg., li, 193; and Am. Jour. Orthop. Surg., 1910.
[3] Ann. of Surg., 1907.
[4] Ztschr. f. orthop. Chir., xxi.
[5] Ann. of Surg., lix, 297.
[6] Ibid., April, 1907.
[7] Ibid., lvi, 876.

for five months. Sudden weakness and loss of sensation in both hands and the right leg then developed. From this he recovered by resting, and in subsequent years, following other falls, he had urinary incontinence and paralysis from which he recovered. Finally after a fall

FIG. 99.—Photograph of Ryerson's case of cervical subluxation. (Kindness of Dr. Ryerson.)

on the ice he developed paraplegia, urinary and fecal incontinence, and weakness in the arms. A roentgenogram showed fracture of the odontoid, not in its neck, but deeply down through the extreme upper part of the body of the vertebra. The study of the specimen demonstrated that the atlas and odontoid process had been carried forward

evenly and not rotated and that attrition had caused the formation of a false joint, the axis minus its odontoid having been pushed backward and worn down. There was a bony ankylosis of the odontoid process to the arch of the atlas, and that portion of the spine, without the check ligaments, was very insecure. This was a good illustration of the result of the mechanism by "flying start," by giving the blow on the back of the head or neck which expends much of its force on

FIG. 100.—Photograph of Ryerson's case of cervical subluxation. (Kindness of Dr. Ryerson.)

the odontoid. This man has lived for thirty-two years with intermittent paralysis, his cervical spinal cord segment being balanced all the time on the borderline of safety.

Two cases of subluxation of the atlas were reported by Ely.[1] The first, a boy aged thirteen years, had rheumatism preceding a fall on the ice, which he concealed, and a stiff neck went undiagnosed. The second

[1] Ann. of Surg., liv, 20.

case followed a fall down an elevator shaft with an asymmetrical head position and irregular sensory and motor paralysis. Pilcher[1] reported a case which was under observation for ten years. The man fell, striking his forehead, and had a paraplegia, and four months later open operation was done. No fracture was seen, but the atlas was dis-

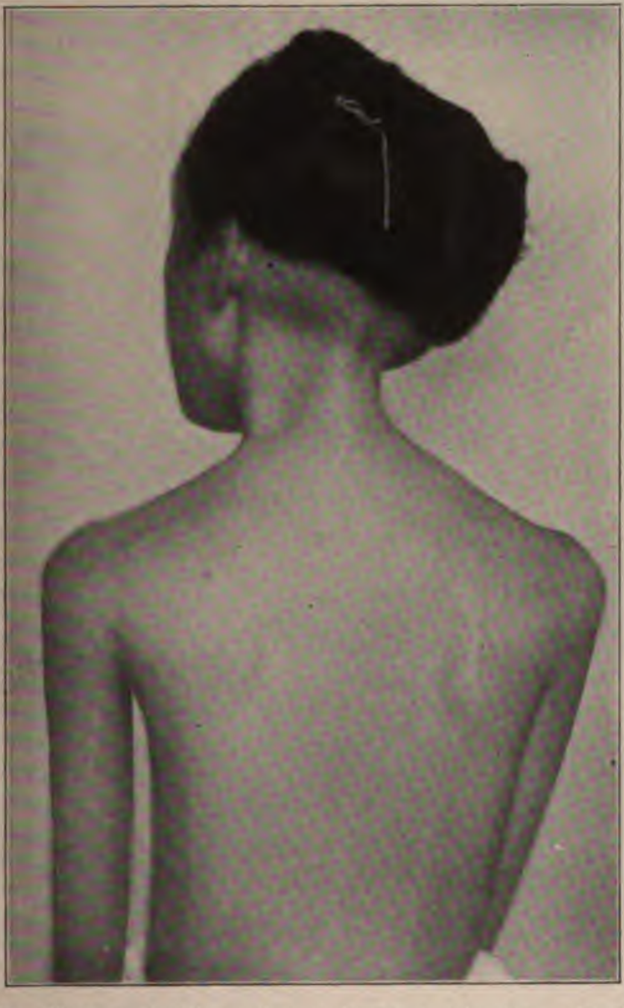


FIG. 101.—Photograph of Ryerson's case of cervical subluxation. (Kindness of Dr. Ryerson.)

located forward on the axis, and the condition could not be corrected. Nine years later he could walk, but one arm remained paralyzed. Examination after that time showed the head rotated to the left, and

[1] Ann. of Surg., li, 208.

a bony callus uniting the atlas and axis could both be felt and demonstrated by the Roentgen rays.[1]

The cervical subluxations are characterized by a fixed position of the neck with great rigidity of the muscles. Torticollis is differentiated by the fact that the sternocleidomastoids are not more concerned than other muscles. Satisfactory and quick diagnosis is aided by the roentgenogram.

An exhaustive study of the subluxations of the atlas upon the axis has been made by Ogilvy,[2] based on the study of 46 reports on the

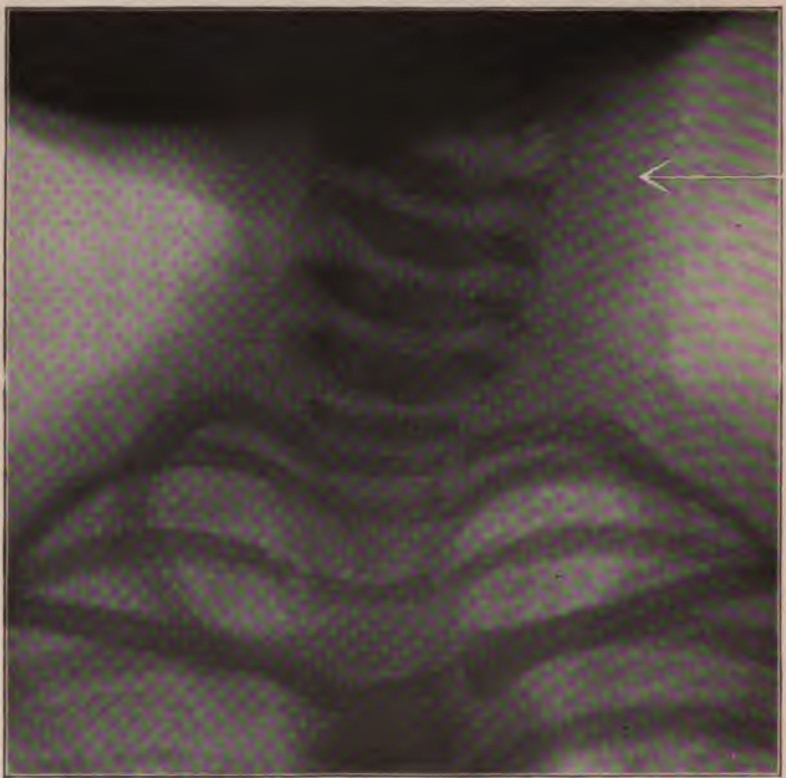


FIG. 102.—Roentgenogram of Ryerson's case of spinal subluxation.

subject. He added his own case in a fourteen-year-old boy who sustained a bilateral flexion subluxation forward of the atlas, while pitching a baseball. Attempts to reduce this by manipulation failed, but his condition improved, and Ogilvy considered that fear of a sudden

[1] Eisendrath, Ann. of Surg., xlii, 245; Bogardus, Inter. Jour. of Surg., xxiv, No. 2; Thomas, Med. and Surg. Reports, Boston City Hosp., 1900, 11th series; Walton, Boston Med. and Surg. Jour., 1903.

[2] Am. Jour. Orthop. Surg., 1914, p. 314.

increase in the amount of displacement, with danger of death, grew less as time passed. He advises early reduction if the patient is seen

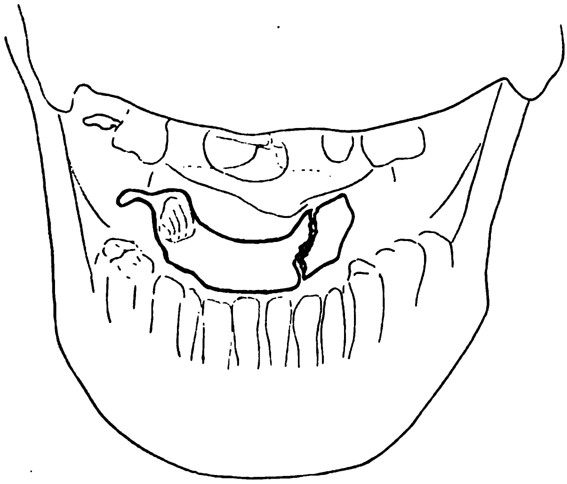


FIG. 103.—A case of fracture of the axis in a woman diagnosed originally as neuritis of the occipital nerve. Roentgenogram made through the open mouth.

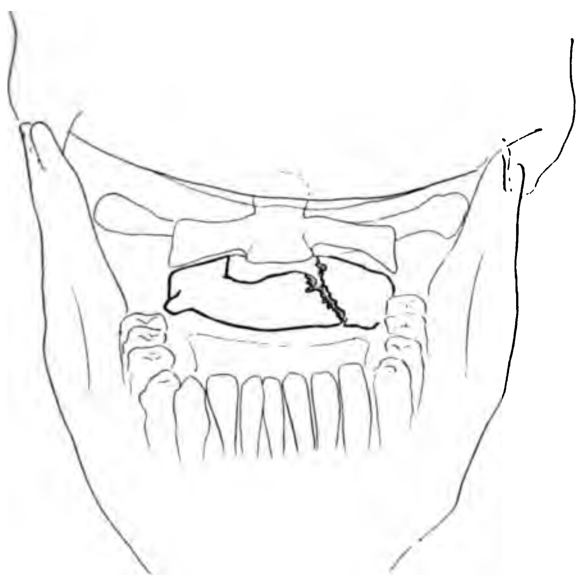


FIG. 104.—The author's case of fracture of the axis. The odontoid was uninjured. The patient had tried to work for three weeks after falling four feet onto his neck and came to the hospital finally because of occipital pain. Roentgenogram through the open mouth.

shortly after the accident, and later treatment in cases with distressing symptoms.

Griffith[1] reported 3 cases of partial luxation of the atlas on the axis. Total dislocations of the spine in the neck are very rare and

Fig. 105

Fig. 106

Figs. 105 and 106.—Position in which the patient with fracture of the axis, shown in the preceding figure, held his head.

Fig. 107

Fig. 108

Figs. 107 and 108.—Head cast used for cervical vertebræ fractures.

concern usually the 3d to the 6th cervical. Meyer's[2] case was of the 4th cervical forward, reduction being made under scopalamine-mor-

[1] Am. Jour. Orthop. Surg., 1914, p. 332.
[2] Deut. Ztschr. f. Chir., Leipzig, cxxix.

phine anesthesia. Many are combined with fracture, but a few have not been so connected. Earlier cases were reported by Steinmann,[1] among which was the first one confirmed by Roentgen rays. Riedl[2] and Derby,[3] the accident to whose case occurred during sleep, have reported cases. Malkitz[4] collected 9 cases, 4 accompanied by fracture, and Quetsch[5] 3 cases without fracture.

Treatment of Cervical Fracture-dislocations.—Simple unilateral rotatory displacement can very often be reduced by manipulation. This consists in the operator's first freeing the dislocated articular process by lifting the head and then rotating it into place with dorsolateral flexion. As a guide to manipulation it is recalled that the chin always points to the side opposite the main lesion. If reduction is accomplished and there is doubt of the fracture of the odontoid, a

Fig. 109 Fig. 110

Figs. 109 and 110.—Views of patient at time he left hospital. There is little deformity and no pain.

Thomas or Calot plaster collar or a plaster helmet should be worn for many months. Ryerson[6] reported a successful reduction by manipulation of a subluxation of the 3d cervical vertebra of six months' duration (Figs. 99, 100, 101, and 102). It is also possible to aid reduction by digital pressure in the pharynx. The subsequent immobilization should be long; fatal results have followed early removal of the protection. Less severe displacement can be treated by chin straps and head harness, with a ten-pound extension weight over the head

[1] Arch. f. klin. Chir., 1906, Bd. lxxviii.
[2] Wiener klin. Wchnschr., 1907, No. 2.
[3] Bristol Med. Jour., July 23, 1910.
[4] Arch. f. Orthop., Mechan. u. Unfalls Chir., Bd. ii, Heft 4.
[5] Münch. med. Wchschr., 1912, No. 18.
[6] Am. Jour. Orthop. Surg., February, 1910.

of the bed, which is elevated to give counter-extension from the body slipping down (Figs. 103 to 110).

Operative treatment, as devised by Mixter and Osgood, is indicated when there is much pain and reduction cannot be made permanently. A four-inch incision is made over the suboccipital spines, the hooked spine of the axis is identified, and the forwardly displaced posterior arch of the atlas is exposed. A strong suture of braided silk soaked in compound tincture of benzoin is passed through the arch, avoiding the spinal cord. Pressure on the anterior arch is made by the finger in the pharynx, and traction is made by the ligature on the posterior arch until reduction is accomplished. This is held and the atlas is anchored by a fastening of the silk ligature around the spine of the axis. A prepared leather cuirass or plaster-of-Paris dressing is applied and left on for at least two months.

FRACTURE-DISLOCATIONS OF THE CERVICAL AND FIRST TWO DORSAL VERTEBRÆ.

This division, excluding the atlas and axis, is indicated because of the source of the brachial plexus from the last four cervical and first dorsal pairs of nerves and the origin of the phrenic at the level of the third and fourth cervical vertebræ. In the lower cervicodorsal region the symptoms are variable; the resulting paralyses involve the arms and chest, but the motor and sensory findings may differ widely. Extension of the paralytic process, which at first may have involved the trunk no higher than the umbilicus, is common, the first thirty-six hours after accident determining the limit to which it will go. Hyperesthesia in the arms accompanied by sharp burning pains or nerve pressure, is often present and is a most distressing symptom because manipulations, or contact against the arm, increase the trouble. Muscle spasm is also found. If there are irritative pains in the arms with no absolute paralysis above the abdomen, the process will probably extend to the arm and may be partial. When the sixth cervical is fractured or dislocated on the seventh with cord damage, the intrinsic muscles of the hand are paralyzed, and the arms seek a position of rest, lying on the chest. When the fifth cervical segment is involved, the arm is usually abducted, the forearm flexed, and the whole extremity rotated outward. There is loss of sensation of the whole arm except at the shoulder.

Lesions of the midcervical region may involve the phrenic by direct damage or the extension of a hematomyelia.

When the accessory chest muscles of respiration are involved, the diaphragm carries on the act, pushing the abdominal muscles out at each respiration. No strong expulsive efforts can be made to clear the bronchi or throat of mucus, and râles quickly appear in the chest. This mucus stasis and a recumbent position lead to early death in most cases. The extension of hematomyelia may cause involvement

of the phrenic within a few hours, the respiration and pulse falling to a low rate before death.

Physical examination may detect no deformity, crepitus, or local tenderness. Pressure along the spine may increase the local pain, or an abnormal mobility can be detected. The subjective sense of crepitus is also possible, although the examiner may not be able to feel it. Neck and head position vary. The head may be in a normal position, with tense cervical muscles which aim to protect against painful or dangerous movement. The head may also assume a rigid position of flexion and rotation as described under the atlas and axis injuries. Spellissy[1] reported a dislocation of the sixth cervical vertebra by the jackknife mechanism. The man's temperature rose from 94° to 103° in sixteen hours; death ensued in twenty hours. The gross pathology was a rupture of the common posterior spinal ligament, a stripping of the anterior ligament from the vertebral bodies, and a complete posterior dislocation of the sixth and upper cervical vertebræ in one mass. The cervical cord was nearly completely severed, and the free hemorrhage found between the divided ends extended down to the level of the fifth thoracic.

Some observers have also reported instances of self-reducing dislocations of the cervical spine without fracture. Grossly and by roentgenogram, there is no evidence of fracture, but paralyses may be present. Autopsy findings show no bone lesions, but the cord shows evidence of pressure opposite the intervertebral cartilages, as if it had been compressed between two dislocated vertebræ which had immediately resumed their normal position.

I have notes on a fracture of the transverse process of the seventh cervical vertebra with paralysis of the eighth cervical and first dorsal nerves much like a lower arm type of brachial plexus paralysis (exact reference mislaid). Open operation revealed a small loose fragment of bone which was depressing the root of the eighth cervical nerve. Removal was followed by relief from the cramps and by other improvement.

Three months before writing this I operated on a case of fracture of the fifth and sixth cervical vertebræ involving the laminæ and spines. There was paraplegia and complete paralysis of one arm, the other arm being but partially affected. Laminectomy of the fifth and sixth cervical vertebræ was done, and the dura was apparently intact. The cord bulged out into the opening made in the bony covering, and the dura was gently slit open for drainage. There has since been complete recovery of motion in one arm and one leg; the other arm still shows a paralysis of the flexors of the hand and fingers, but the extensors of the wrist are functionating. If no further improvement develops, a tendoplasty will be performed to utilize one of the active extensors through the grafting of it into the flexor group. The other leg is spastic but the patient can walk with a cane (see Figs. 111 and 112).

[1] Ann. of Surg., xlvii, 137.

FIG. 111.—Lateral view, showing the amount of flexion of the head after operation. Note the scar visible on the left side of the neck.

FIG. 112.—Postoperative scar after laminectomy of fifth and sixth cervical. Note how well the head is held up and the incision lateral of the midline.

Diagnosis is difficult even with the aid of the Roentgen rays. It is also difficult to hold the sensitized plate at a low enough level to obtain good views of the lower cervical vertebræ, on account of the interference of the neck and shoulder tissues. Suspected injuries in the cervical region, with or without paralyses, must be carefully immobilized, if operation is not indicated or refused. Many cases are quickly fatal, over one-third dying within the first week, many within the first forty-eight hours. A few instances of prolongation of life for months have been recorded.

FRACTURE-DISLOCATIONS OF THE DORSAL REGION.

Symptoms.—Symptoms of fracture of the dorsal vertebræ below the first two are more striking than those of the cervical vertebræ, and diagnosis is easier. The nerves in the dorsal region have a simpler method of exit from the spine, and the level of injury is easier to map out, both from the nerve symptoms and the external examination. Most of these fractures involve the body of the vertebræ, and there is apparent deformity arising from their crushed condition. The hiatus between the spines of the injured vertebra and the one below can in many instances be palpated by deep pressure. Here also the motor and sensory paralysis may vary, especially in the lower dorsal region, the sensory disturbances failing at first to reach the height of the motor. Patellar reflexes are generally lost, plantar reflexes vary, and the bladder and rectum are usually involved. If there is recovery, a spastic paralysis of the legs follows, and contractions may also be found. If the lumbar enlargement of the cord is injured, there are irritative pain symptoms in the legs. Hematomyelia also occurs in this area. The immediate prognosis is better than in cervical injuries; the remote causes of death, such as urinary tract infections and myelitis, depend on the involvement of the bladder and the use of the catheter.

The tenth to the twelfth dorsal are the most frequent site of injury. Sprain fracture, by muscular action, is more frequent in the dorsal region. This involves the spinous process, which is displaced downward, and non-union generally results. Gurlt[1] found 21 cases of complete pseudarthrosis of spinal fractures, 4 involving the spinous processes. Skillern[2] reported 1 of the first dorsal. The loose pieces should be excised, if there are any symptoms.

Dislocations in the dorsal region are more commonly between the twelfth dorsal and the first lumbar, although the inferior articular processes do not favor luxation, because they look forward and outward like the lumbar vertebræ. The displacements may be to either side by rotation or directly forward and backward. These may accompany fracture, but simple forward dislocation is possible by a flexion of the spine which raises the inferior articular processes of

[1] Handbuch, 1862.

[2] Ann. of Surg., June, 1913, p. 908.

the upper vertebra above and away from the superior processes of the lower vertebra.

Bilateral, forward and backward dislocations are those usually found. Bilateral in opposite directions are rare; lateral alone very rare and are caused by a combination of extreme flexion of the trunk and direct violence at the point of greatest bending on the side or back. Such a mechanism is offered by crushing injuries under a heavy falling body or blows from moving cars, etc.

Symptoms and diagnosis are much the same as in fractures, and the absence of crepitus does not prove that fracture is absent. If the deformity can be reduced and has no tendency to recur, dislocation is probable. The prognosis is like that of fracture; the higher up, the less favorable, and the greater the pathology of cord injury, the less favorable.

Treatment.—Treatment is applied by extension of the shoulders with the hips fixed or counter-extended on the Hawley table, and after-treatment is like that of fracture, a long rest in bed or a plaster jacket (Fig. 113).

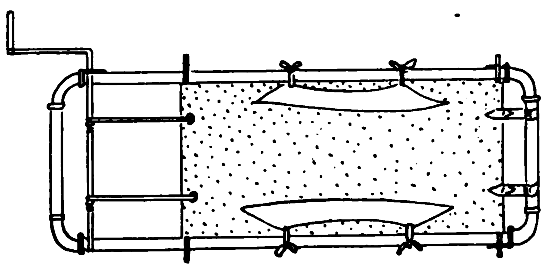


FIG. 113.—Bradford frame with adjustment for tightening the canvas. Slits are cut and tied back so that the patient can be easily handled.

FRACTURE-DISLOCATIONS OF THE LUMBAR VERTEBRÆ.

Symptoms.—The cord ends at the lower level of the first lumbar, so that injuries at or below this point involve the cauda equina. Fractures and dislocations are rare. Borchard[1] reported a case of successful reduction and complete cure of forward dislocation of the first lumbar. The symptoms cover bladder and rectal retention, loss of patellar and plantar reflexes if the lesion is complete, and partial or total paralysis of the legs. Because the cauda is composed of separated nerve bundles, many may escape damage, and the lesions are partial with irregular findings of motor paralyses up to the level of the bone injury. Spastic gait and contractures may follow. Considerable deformity may be present with no nerve symptoms. In Borchard's case there were severe nerve pressure symptoms with paralysis. An open operation was done, and the first lumbar vertebra was pulled back into place and wired, the roentgenogram showing complete reduction.

[1] Arch. f. klin. Chir., Berlin, cv, No. 2.

Prognosis.—The prognosis is much better than in cervical and dorsal injuries but is on the whole poor. Many recoveries have been recorded, but if there is not complete replacement or release of pressure on the cauda, permanent paralyses result in restricted activity. The bone lesion may heal with a deformity or a weakness in support which precludes much function of the back. Walking with bent or crooked position often results; a few cases obtain excellent function in spite of deformity. On account of the regeneration of the neurilemmatous nerve in the cauda, these injuries which involve it offer special inducements for operation. When the progress of the case ceases, or if no spontaneous attempt at recovery is found, the spine should be opened and pressure removed or nerves sutured, to meet the conditions present. No arbitrary time for this operation can be set; improvements have followed nerve suture after many months. As a rule, however, under favorable conditions, the attempt should be made within six or eight weeks after the accident.

Dislocations of the lumbar vertebræ are uncommon. Most injuries are a combination of fracture and dislocation not only of the lumbar region but of neighboring vertebræ. Severe crushing injuries which involve the soft parts and the abdominal viscera are concomitants. The ligaments are torn, and the intervertebral cartilage may be disintegrated and chips of bone pulled off the edge of the bodies. Spinous processes and ribs may also be broken. The mechanism is probably in a majority of instances a hyperflexion. The lumbar vertebræ are protected by the strong and heavy lumbar muscles and the interlocking of the articular processes, as described under Fracture. The bodies of the vertebræ are also heavy and are protected from jars and strains by the thick intervertebral cartilages, which give elasticity. Antero-posterior flexion may cause a pure dislocation, but it is almost impossible for lateral flexion to cause movement out of place unless the transverse processes are broken.

The symptoms and prognosis are about the same as in lumbar fractures, the paralysis usually being of partial character on account of the division of the cauda equina into isolated bundles. There is local deformity, pain and tenderness, and walking disability.

Treatment.—Anterior dislocations are probably best reduced by open operation, as in Borchard's case. Manipulation, traction on the shoulders, and forward pressure on the lower part of the displaced spine, might cause reduction. Backward displacements have been replaced by pressure on the deformity portion aided by extension or counter-extension in the long axis of the spine. As in other areas, if there are no nerve involvements, and manipulations fail to correct the deformity, it may be ignored and allowed to heal firmly in a plaster jacket worn for four to six months.

Course and Prognosis.—It is impossible to make general statements covering these two points, as they are so inextricably mixed with pathology and treatment, and those paragraphs must be read to cover the ground. The course of fracture itself involves merely the changes

that occur in the bone. In simple fracture of a spine or transverse process, union may occur as in some of the cases cited. This is bony, if fragments are in apposition. Rarely an excess of callus is thrown out to cause pressure on the nearby nervous structures. Most unions are bone; non-union of remotely placed transverse or even spinous processes is common. So few of the cases recover or are followed to death for autopsy findings that there is meager information to be had on the subject of subsequent bone changes. Gurlt, in his *Handbuch*, records 21 cases of complete pseudarthrosis, 5 of spinous processes, 3 of transverse processes, and 13 of the arches of the lumbar vertebræ

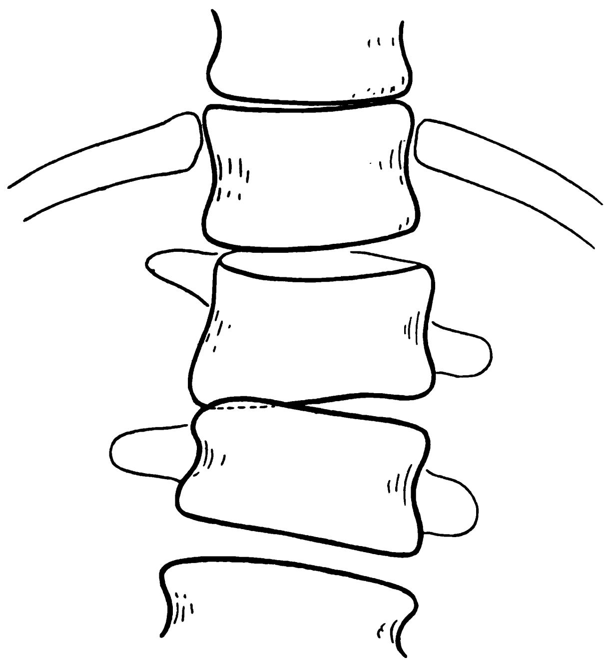


FIG. 114.—Old fracture of the second lumbar with rotary displacement.

and sacrum. Some of these cases have been considered as congenital defects, and their sequence to fracture disputed.

Fractures of the body often lead to absorption of a broken-off fragment. If several bodies are comminuted, they may all become adherent in a mass of bone callus, a gibbus forming, and a rigid spine resulting. If a single body has been injured, it tends to wear down and assume the shape shown in Fig. 114 after many years. Projecting callus or pieces of bone become rounded off unless osteo-arthritic changes occur in connection with the same changes in other bones of the body. This causes bony overgrowth and lipping projections so commonly seen in chronic osteo-arthritis of the spine. Bony union is very slow in the vertebræ. Infection and osteomyelitis at the site of the injury

are common, probably on account of the deficient blood supply and the size of the bones.

The damage of the cord is a very different matter, as the pathology of the repair shifts to the conditions governing nervous tissues. The cord may be completely destroyed and show no evidence on examination of its envelope. Crandon found a case in his collection at the Boston City Hospital where death occurred one month after fracture of the first dorsal with complete degeneration of the cord at that level without macroscopic changes in its covering. Reference to the elementary anatomical description of the cord in the beginning of this chapter leads to a conclusion that a lesion of continuity of the cord may heal by scar tissue, or the torn dura may close over in the same way. Improvements after severe injury are probably caused by the fact that some nervous fibers in the cord escaped destruction and later resumed function. This is possible even if the medullary sheath is destroyed, because the naked axis-cylinders continue their function. If a cord is torn and sutured, anatomical regeneration may occur, but functional repair does not. After severe injuries secondary degeneration ensues, which is the result of the injury itself and does not cause compression symptoms. This degeneration follows injury whether the compression is removed at once or not, because these highly specialized tissues are quickly destroyed and do not regenerate.

It is expected, then, that the course of concussion of the cord, where there is no anatomical change and the function is suspended, will be short and offer an excellent prognosis. Contusions, with or without bone lesions, may also be of no consequence. But if the cord matter has been destroyed, the result is severe and permanent. The mildest change consists in a traumatic zonal inflammation; the nerve fibers may be forced apart by blood or transudate with a temporary suspension of function but no permanent axonal destruction. Effusion of blood about the cord is not important; if pressure symptoms are caused they usually clear up within a month.

In hematomyelia, which involves the softer or less resistant gray matter, some nerve elements are destroyed, and there is more or less pressure on the surrounding area. After absorption of this blood and the destroyed nerve tissue, a cavity is left, and although partial functional recovery has become established there is some permanent weakness of the area supplied by the segment.

Krause[1] mentions the reported cases of cords regenerated after section.[2] Fowler's case of complete severance after gunshot made a partial recovery and obtained some bladder and rectal control and could get about on crutches. Fowler waited ten days before operation, while the Stewart-Harte case, which made practically a com-

[1] Chir. des Gehirns u. Rückenmarks, 1911, Bd. ii, 812.

[2] Stewart and Harte, Philadelphia Med. Jour., 1902, ix, 23, and Tr. Am. Surg. Assn., 1905, 93; Fowler, Ann. of Surg., 1905, xlii, No. 4; Shirres, Montreal Med. Jour., April, 1905, xxxiv.

plete recovery, was operated on within three hours. Arrangements have been made for the recovery of this cord when the patient dies.

Marie[1] has found that in his service at the Salpêtrière only 5 patients out of 18 with wounds of the spinal cord had died after six months. He showed before the Académie de Médecine 5 patients who had been struck by projectiles in the cervical region. All had suffered immediate and persistent paralyses of all four limbs with sphincter trouble, and all had made consistent progressive improvement, so that several could walk and run, and all could dress and feed themselves.

When the lesion has caused bladder and rectal paralysis, the bladder distends and an incontinence of retention is soon established. If no catheterization is done, there is much less danger of cystitis developing, and as the patient is insensible to the distention, the bladder should not be relieved in the early days after injury. When cystitis does develop, it should be treated in accordance with surgical principles governing infections of the tract. Very rarely a bladder may be ruptured or its walls may slough from pressure and hasten death. Lesions of the upper dorsal and lower cervical regions often end in death from pneumonia or hypostatic congestion in a few days.

Pressure necrosis, sores on the buttocks, thighs or back, do not tend to spread rapidly after the first sloughing, if they are given prompt attention. In some cases of incomplete lesion they heal and later break open again. They may become infected from urine and feces, extend quickly, and hasten the end by septic absorption and exhaustion. The sacrum or femora may be exposed and secondary osteomyelitis and meningitis follow. Marie,[2] basing an opinion on experiences in the war, reported to the Académie de Médecine that he did not believe that bed-sores were the result of trophic disturbance, but were due to prolonged pressure and the infection from discharges. The slightest soiling of the surface must be cared for by washing and powdering, and the patient's position should be shifted every two hours, night and day.

Patients with incomplete lesion who survive the fracture injury and its immediate consequences, may live for many weeks, the course ending with a high, irregular fever. Others live for years, finally succumbing to pressure necrosis or kidney infections. Still a smaller proportion regain reflexes and motor and sensory power, beginning with muscular twitchings, and may become ambulatory with crutches.

Years after fracture with no cord symptoms, secondary degeneration may appear. Pachymeningitis and death follow.

A case of medicolegal interest touching the prognosis of spinal injuries was recorded in an abstract in the *Journal of the American Medical Association.*[3] This was a damage suit for injury of the spinal cord with permanent crippling which destroyed all earning capacity. (Padricks *vs.* Great Northern Railway Co., Minn., 150, N. W. R. 807.)

[1] Jour. Am. Med. Assn., lxv, No. 2, p. 183.
[2] Ibid., June 19, 1915, lxiv, No. 25.
[3] Ibid., No. 20, p. 1680.

The plaintiff was awarded $35,000, which the court considered excessive and reduced to $30,000 because one-third of the amount represented a sum sufficient to compensate for the lost earning capacity and the rest provided for personal attendance and compensation for suffering and deprivation of the enjoyment of life. This last factor was considered an elastic one, but no money compensation could even be adequate for serious permanent personal injuries, and the amount of recovery must be limited by courts to protect the various interests involved. The plaintiff did not appear bed-ridden, he could move about somewhat, and his mind was unimpaired.

Treatment.—Fractures of the spine demand the same general treatment given fractures anywhere in the body, namely, rest and immobilization after reduction of deformity, if this last is possible. Because the bone lesion is of less importance than the cord injury, the first thought in treatment should be to preserve the cord from any further damage. When an individual sustains an injury to the spine, he should not be moved about or rolled over by anyone until the medical man is present. He should be kept in the position in which he is found, and transportation to the place of treatment should be on a flat stretcher in the same position. This requires the most delicate handling. We know that fractures of the upper cervical region have a high mortality, and there is often no chance for treatment. It is also best not to decide treatment on any statistical basis, as the lesions of reported cases are so different.

Depending on the character of the lesion, treatment is (1) expectant and palliative; (2) reduction and fixation in a permanent dressing; (3) operative, by laminectomy, either primary or secondary.

1. Expectant treatment is applied to two types: (*a*) Those cases with fractures of process or which have no cord symptoms, and (*b*) cases of undoubted complete transverse lesion, which offer no hope for recovery and are moribund. These patients are put to bed and made comfortable, and heat is applied and antishock measures adopted. If there is severe irritation pain, morphine is used. This treatment does not include active means to relieve the bladder, which I believe are uncalled for under any circumstances. The catheter should *not* be used; the bladder is allowed to distend until an incontinence causes a dribbling away of the urine, morphine being given to control what pain develops. This treatment avoids cystitis, and in the very mild lesions a temporary interference with bladder action will later be rectified. The patient can be put on a Bradford frame or a water bed. In symptomless fractures of the spinous processes a plaster jacket is applied. Spinal puncture may relieve pain and intraspinal pressure, as suggested under Diagnosis.

2. Reduction and fixation in a permanent dressing is reserved for those cases with a bony deformity without cord injury, and for those with cord symptoms who refuse open operation. The patient is placed on the Hawley or flat table with means for suspension of the back, or if the gibbosity is great, he is rolled over, the body being turned as

a whole, and extension is made on the trunk and legs in opposite directions. This extension is made slowly in the line of the column axis, and is checked by constant knowledge of changes in the condition of the cord as shown by reflexes and changes in sensation and motion during the slow procedure of reduction. At the slightest sign of pressure on the cord, the attempt must cease, and open operation performed. When the deformity is straightened out, a plaster jacket or corset built up from the iliac crest as in Pott's disease, is applied with the body in suspension. Cases of marked deformity are more safely treated by open operation and reduction under the eye. Burrell studied 244 cases of spine fracture treated at the Boston City Hospital from 1864 to 1905, and in the time prior to 1887[1] he had advocated in his treatment the correction and cast plan. In 16 cases so treated by immediate rectification and plaster, 3 died, 3 were not improved, and 10 were improved. Eliot[2] records a case in a thirty-four-year-old male with depression of the twelfth dorsal and a projection of the spine and a ¾-inch dislocation in the horizontal plane. There were paralyses. The back was stretched and a cast applied, and in eight months the patient could walk well.

For other references see footnote.[3]

3. **Operative Treatment.**—Primary laminectomy is undoubtedly indicated in many cases and should be done at once after painstaking examination of the patient for decision as to the character of the cord lesion. If there is a marked kyphosis which manipulation does not affect, even in the absence of cord symptoms, operation is indicated for an attempt to straighten out the column, or by laminectomy to forestall the chance of compression. Nearly all surgeons who deal with these fractures favor the statement that in known complete transverse destruction of the cord, operation is useless and may hasten death from shock or infection. Though this may be agreed upon as basic, it is not so easy to have an agreement on the symptoms which prove absolute destruction, and the few cases of suture of the cord and recovery after injury or gunshot recorded above would encourage the hope that this step should be taken in the seemingly hopeless cases.

A roentgenogram of the spine should be made to determine the position of fragments, displacements, and foreign bodies. If there are symptoms of complete transverse lesion, with an irremediable cord, do not operate.[4]

These symptoms are:

1. Complete flaccid paralyses below the lesion.
2. Complete loss of all forms of sensation, anesthesia with sharp demarcation.

[1] Med. Com. Massachusetts Med. Soc., 1887, xiv, No. 1.

[2] Ann. of Surg., lii, 409.

[3] Gurlt, Handbuch, collection 270 cases; Thorburn, Manchester, Med. Chron., 1892, xvi, 73; Morton, Practitioner, 1901, lxvii, 307; Lloyd, 227 cases, Philadelphia Med. Jour., February 15, 1902; Jour. Am. Med. Assn., 1901, p. 1014.

[4] Thomas, Boston City Hosp. Med. and Surg. Reports, 1900; Sencert and Auvray, Bull, Méd., Paris, 1909, p. 909.

3. Absence of reflexes.
4. Complete paralysis of bladder and rectum, with tympanites and priapism.
5. Absence of *variation* in symptoms.
6. Absence of irritation phenomena, such as pain and twitching.
7. Vasomotor paralysis, heat and sweating of parts.
8. Early appearance of reaction of degeneration in muscles.

Partial Lesions.—Motor paralysis is not absolute and may be very slight. Single groups of muscles alone may be involved. There is also a variation in the quality of the paralysis from the flaccid to the spastic type, the sensory and vasomotor symptoms are not complete, and the bladder and rectal disturbance is also incomplete. In addition there is evidence of irritability of the spine with pain, and the reflexes gradually show some improvement.

Allen has done some very instructive experimental work[1] in which he succeeded in determining the amount of impact which can be sustained by the spinal cord of an animal with recovery. He showed that a median longitudinal incision into and through the spinal cord produces few symptoms, and succeeded in producing an uneventful recovery in dogs whose spinal cord had been subjected to a force of hyperimpact and immediately treated by this operation. Control dogs did not recover. The practical conclusion was that fracture dislocation of the human spine with existing symptoms of transverse lesion should be subjected to laminectomy at the earliest possible moment, and if the cord was not completely severed, it should be drained of the products of hemorrhage and edema by a median longitudinal incision through the dura and cord.

Laminectomy is a major operation and has its dangers, but many of them arise from the critical condition of the patient from the shock of the accompanying trauma. Coley[2] thinks its dangers are overrated, and Bailey and Elsberg[3] consider it a major, but believe the burden of the mortality in laminectomy statistics should be borne partly by the accompanying disorders. By exclusion of 5 moribund cases, they performed 29 primary laminectomies without a death and believe that even in the absence of increased pressure within the canal or a discoverable lesion, the operation and incision of the dura may be of great benefit. A general statement that partial lesions, injuries with displaced bone fragments, or dislocations shown by the roentgenogram, cases of failure of reduction by manipulation in cervical cases, and fracture of the arches with pressure symptoms and caudal lesions, should be given early operation by laminectomy, is conservative, and is subscribed to by such men as Krause,[4] Estes,[5] Elsberg,[6]

[1] Jour. Am. Med. Assn., September 9, 1911.
[2] Ann. of Surg., lvi, 60.
[3] Jour. Am. Med. Assn., March, 1912, p. 675.
[4] Loc. cit.
[5] Am. Jour. Surg., 1910, xxiv, 341.
[6] Ibid., xxviii, No. 1; 39; Internat. Abst. Surg., June, 1914; Ann. of Surg., lviii, 296.

Frazier,[1] Bottomley,[2] Allen, McWilliams,[3] Taylor,[4] and Miller. Coriat and Crandon[5] reported 3 cases of spinal cord injury and believe that they demonstrated two important facts; first, the value of an exact regional diagnosis of the lesion in the cord, thus limiting the extent of the laminectomy, and second, the excellent results which may be obtained in spinal cord surgery from early operation.

When the cord is crushed in one segment, there may be damage at a distance from the main lesion by hemorrhage, as described in the pathology, so that even if relief of pressure were afforded by local laminectomy the distant injury would remain. Consequently after operation and removal of laminæ the surgeon may not have removed all pressure, and he must still be in doubt. For this reason it is often best to wait a few days to remove the possibility of contusion of the cord, to attempt to establish the permanency of apparent transverse lesions. Shock can be overcome in a few hours, and the operation does not threaten life and may save some cord axones from destruction. Pain, if present, can also frequently be relieved. Those cases which are moribund with great bone displacement and a high and rising temperature, must not be subjected to operation. Late laminectomy is advocated because it avoids shock, and if the injury to the cord is not irremediable at the time of accident, it is rare for bone or other pressure to cause permanent abolition of function. If a partial lesion is not operated upon early, it should be opened when there is not improvement, or when a retrogression of symptoms is noted. The same statement applies to hematomyelia and hematorrachis with retrogressive changes caused by the blood-clot or adhesions. If the deformity has not been reduced, or excess callus causes symptoms, late laminectomy should be done. Thorburn,[6] after 7 laminectomies became pessimistic of their value, Lloyd,[7] in a table of 82 immediate laminectomies and 103 late operations concluded that the statistics were decidedly against immediate operation, but that operation should be done when shock was past. Other men who favor late operation for the reasons mentioned above are Krause, Oliver,[8] Bottomly, Eliot, Taylor, Miller and DeQuervain, quoted by Powers, 208 operated cases.[9] Early or immediate operation has fallen into disrepute largely because the cases were not selected and complete transverse lesions and moribund patients were operated on.

C. E. Black's collection of 552 cases from the literature gave the following figures: Of the operated cases 49.2 per cent. recovered; of the non-operated cases 25 per cent. recovered and 65 per cent. died.

Cervical region mortality, operation 71 per cent., without operation 85 per cent.; dorsal region mortality, operation 48 per cent., without

[1] Surg., Gynec. and Obst., March, 1913.
[2] Loc. cit.
[3] Ann. of Surg., xlviii, 140.
[4] Loc. cit.
[5] Boston City Hosp. Med. Reports, 16th series, p. 235.
[6] British Med. Jour., February 15, 1902.
[7] Philadelphia Med. Jour., February 22, 1902, p. 324.
[8] Cincinnati Lancet-Clinic, November 7, 1903.
[9] Med. Rec., New York, lxxix, 667.

operation, 64 per cent.; lumbar region mortality, operation 26 per cent., without operation 50 per cent.

Gunshot wounds of the spine may cause severe injury *without* penetration of the cord, and they offer special indications for treatment. Treatment of these injuries or fractures depends partly on the direction from which the shot came and the amount of cord and bone damage. If from behind, the bullet may enter the cord, penetrate it, and become buried in the body of the vertebra or other tissues, with little additional harm, other than the destruction of the cord. In the last year I have had one case of shot from the rear with fracture of a lamina and complete destruction of the cord, and another of shot through the chest with complete severance of cord, the bullet lying just under the skin to one side of the spinous process of the eleventh dorsal. The injury must be considered from the standpoint of (1) injury to the cord; (2) fracture of the bony parts; (3) injury of thoracic or abdominal viscera. Puncture of organs may demand immediate laparotomy or other operation, or shock may be so great that none can be undertaken. The wound tract should be disinfected, and after shock is past the spine can be opened to relieve pressure from clots or bone and to permit drainage and minimize chances of infection.

Suspension of function may be caused by contusion or by a pulping of the nervous structures without damage to the dura. Pilcher[1] recorded a case which involved the fifth and sixth cervical, but which gave no symptoms after one month. A case which concerned the seventh to tenth dorsal was opened by Winslow.[2] There was no penetration of the cord, but there was complete destruction of it, as was also found true of a second case at autopsy. Coley[3] successfully removed a bullet from between the first and second dorsals in a patient who gave symptoms of complete laceration of the cord. There were two pieces of bullet imbedded in the substance, and the final result was full restoration of all function. A similar case was reported by Fort, in the discussion of Winslow's paper, in which complete recovery followed a gunshot which drove a spicule of the transverse process into the cord with symptoms of a complete transverse lesion.

Early operation is favored in gunshots in accordance with Allen's experiments and practical results furnished by clinical cases. Prewitt,[4] after seeing 58 cases of spinal wounds in the Spanish-American war, concluded that where the region is accessible and the patient's condition justifies, it was best to operate. Of these cases 33 were fatal; of 25 operated on 12 recovered. Krajeroski[5] reviewed 32 cases of laminectomy in the literature without removal of the bullet, with 24 deaths. Schmidt[6] shows from the German government statistics that

[1] Ann. of Surg., xxxviii, 812.
[2] Tr. Southern Surg. and Gynec. Assn., xxiii, 432.
[3] Ann. of Surg., lvi, 60.
[4] Ibid., 1898.
[5] Jahresbericht über die Leistungen u. Psychiatrie, 1906, x.
[6] Deutsch. milit. Ztschr., 1904.

of those operated on for spinal injury, 72.5 per cent. recovered and of those not operated on, 24 per cent. recovered.

The mortality from laminectomy for fractures below the sixth dorsal in good hands is not greater than 10 per cent.

Technic of Operation.—As this is a serious operation it should not be undertaken unless indicated and should be performed with gentleness and careful hemostasis. The patient is placed in a semi-prone position, propped up with sand-bags, or is held on a special table with an extension for holding the head while in a prone position, as for craniotomy. Special attention is given to providing room for the respiratory movements of the chest. Frazier states that in the dorsal position a patient expires air in a ratio of 10 to 6 compared to the face-down position, and he therefore uses intratrachial insufflation in spinal operations. The spinous process which marks the selected site of operation is indicated by a double coating of iodine, and a skin incision four inches long is made, either directly over the spines or in a curved line lateral to them. The mistake of opening too low should be avoided through recollection of the anatomical points mentioned in the beginning of the chapter.

After the spines are exposed by retraction, the muscles are reflected on both sides by a sharp elevator or chisel, down to the laminæ. The laminæ are cut through by a laminectomy forceps or by the mechanical or Doyen saw, and the spines are lifted out, after a severing of the interspinous ligaments. Several spines may thus be removed. The opening into the canal may be broadened, if necessary, by a cutting off of more of the laminæ laterally. If the saw is used it must be placed at a right angle to the surface of the laminæ, not in line with the axis of the spine. This removal of bone exposes the dura. Even if no damage to it is seen, it should be opened or punctured by an aspirating needle to detect the presence of blood and to determine the condition of the cord. Allen's procedure may be used. Spicules of bone, pieces of dura, or foreign bodies are carefully picked out of the cord. If suture is believed in, the severed cord or the dura may be stitched together. Dislocations may be reduced. McWilliams[1] reported a case with partial severance symptoms which showed clinically a projection of the twelfth dorsal spine. On opening being made, the articular process of the upper left side of the twelfth dorsal was found empty and directed up and inward. The dura seemed uninjured but arched over the projecting twelfth dorsal, and the transverse process of the eleventh and twelfth dorsal were fractured. The dislocation was reduced by traction on the shoulder and pelvis and a pushing on the opposite lumbar region to rotate the spine, and a prying of the edge of the eleventh dorsal articular process upward with a periosteal elevator. It required great force to establish a reduction. The condition after a year and a half was that of a typically spastic gait but the patient could walk unassisted.

[1] Ann. of Surg., xlviii, 140.

The dura should be left open. The muscles are closed by a buried layer of sutures, the fascia also, and the skin is best closed by a subcutaneous stitch of zero catgut which does not need removal. There should be no drainage.

Osteoplastic exposure of the spinal canal as described by Bickham[1] is not advisable in fresh traumatic cases. It may be used in late operations and has the advantage of not removing more than one spinous process to give a good view of the spine. A composite flap of skin, fascia, and one or more spinous processes, is raised upward through a U-shaped incision parallel to the spines. Hartley's preliminary excision of the spinous process at the base (upper end) of this lap is made through a small incision over that spine. All structures are later dropped back, after the cord has been attended to, and sutured into normal position.

Spinal puncture as a diagnostic and therapeutic means is easily done. This is not the place to discuss the technic, but the surgeon should recall that although the anterior subarachnoid space of the cord is entirely free and open, the posterior space in the dorsal region is divided by interrupting membranes attached in the line of the nerve roots. Lusk[2] has called attention to the anatomy and the paralytic sequels which may follow lumbar puncture. Meningitis after spinal operations is also treated by repeated spinal punctures in connection with a constricting band of Bier's hyperemia around the neck. Klapp[3] has reported 2 cases of meningitis thus treated after gunshots, with recovery.

Bone transplantation to stiffen the spine and afford support after fracture and laminectomy is also an operative step of value. This is done in accordance with Albee's method after the wound of laminectomy has healed and there is assurance of no pressure on the cord and full return of function. This avoids the wearing of a brace or plaster jacket and makes the patient nearly as independent as before the fracture. The transplant should cover the length of five or six spines and every effort be made to establish bony union. Palmer[4] has reported a successful case.

[1] Ann. of Surg., xli, 373. [2] Ibid., liv, 449.
[3] Münch. med. Wchnschr., lxii, No. 5.
[4] Surg., Gynec. and Obst., 1914, p. 664.

CHAPTER XI.

FRACTURES AND DISLOCATIONS OF THE CLAVICLE.

Anatomy.—The clavicle acts as a buttress between the upper extremity and the trunk and is "*f*" shaped with a double curve. There is a convexity forward at the sternal end where the bone is flattened out. The two extremities are composed largely of cancellous bone encased in a thin compacta. The area of the junction of the middle and outer third has a thicker compacta. It is in this weak portion where the two curves of the bone meet that fracture is most frequently found.

This bone begins to ossify before any other in the body, but its ossification centres have little clinical bearing on fracture. At the outer end the trapezius and deltoid muscles are attached, the latter in front. At the inner or sternal end the sternocleidomastoid is found on the back and upper edges and the pectoralis major on the anterior and lower edge. Beneath the bone is the subclavian muscle, at the inner end is the rhomboid ligament which attaches it to the first rib, and at the outer end are the conoid and trapezoid ligaments which bind the clavicle to the scapula. The upper surface of the bone is subcutaneous and palpable for its whole length, and at the ends are found true joints with strong capsular and supporting ligaments, the acromioclavicular joint at the outer and the sternoclavicular joint at the inner end. Palpation of the acromioclavicular joint discovers its position medialward from the acromion process of the scapula. The joint is directed obliquely and lies well within a ruler edge applied along the outer side of the arm projecting above the shoulder. (See the ruler test applied in fractures of the humerus.)

FRACTURE OF THE CLAVICLE.

Causes and Occurrence.—Fractures of the clavicle are caused by direct and indirect violence and rarely by muscular action. Most instances arise from falls on the shoulder, forearm, and hand, with the arm abducted, the stress of the impact being borne by the clavicle in its capacity of support of the arm out from the body. Blows on the elbow act in a similar manner, and the indirect violence is transmitted in the same direction, the point of fracture tending to select a site where there is alteration in the line of bone support. This is in the clavicle at the junction of its two curves. A very large proportion of these fractures occur in children. In 10,702 cases of fracture at the Cook County Hospital there were 538 clavicular fractures. I have also made a study of the fractures of children for a period of

seven years and find that of 1149 consecutive fractures there were 111 of the clavicle, or approximately 10 per cent. This contrasts strongly with 4 cases of fractures of the ribs in children during the same period. Violence from falls which lead to dislocation of the humerus in adults cause bending and compression fractures of the clavicle with little deformity in children. Rarely the bone is broken in adults by indirect violence coming from the arm which bends the clavicle over the first rib. This is probably caused by action of the arm muscles, which suddenly overcome resistance when under great strain in a downward direction and pull the clavicle violently down across the rib.

Direct violence may be applied at any part of the bone and cause fracture by compression, or dislocation by indirect transmission. It is usually received on the most prominent part of the bone in its convexity forward. Blows on the front of the shoulder directed backward usually result in transverse fracture of the clavicle, and blows from above directed downward near the outer end cause fracture or dislocation of the outer end. The ordinary direct causes are weights falling on the clavicular region or run-over accidents.

Muscular action has caused some fractures of the clavicle. If the arm is rigidly fixed in an effort to support strain, the pectoral and deltoid muscles acting together might cause fracture. Extreme extension of the arm backward in muscular action is more likely to cause a dislocation forward of the sternal end of the bone than fracture. Fractures resulting from blows delivered by the arm in boxing or striking are really caused by indirect violence and shock of the sudden impact transmitted to the clavicle and are not to be attributed to muscular action.

Pathology.—Fractures of the clavicle are divided into those of the two extremities, and those of the shaft. The contour of the bone also permits an easy division into fractures of the inner, middle, and outer thirds.

The *shaft*, especially the middle third, is the most common seat of fracture, for obvious anatomical reasons (Figs. 115 and 116). This portion containing the junction of the two curves of the bone suffers from indirect violence, and the line of separation is generally oblique from behind forward and inward, or forward and outward. Fracture may assume any form of single, multiple, complete, incomplete, green-stick, transverse or oblique separation. Open fracture is extremely rare and arises from direct violence of gunshots or run-over accidents. The extremities of the bone are less liable to fracture or to displacement because they are firmly held by the various ligaments and are less subject to displacement resulting from muscular attachment. The usual break in the middle third of the bone is oblique and complete in adults, and transverse in children, with varying separations. If the bone is broken in two places or is comminuted, the fragments may be displaced in any direction in which they are carried by the force. The same statement applies to fractures caused by direct violence.

I have seen a fracture at the junction of the middle and outer thirds in which the outer fragment was turned directly downward and

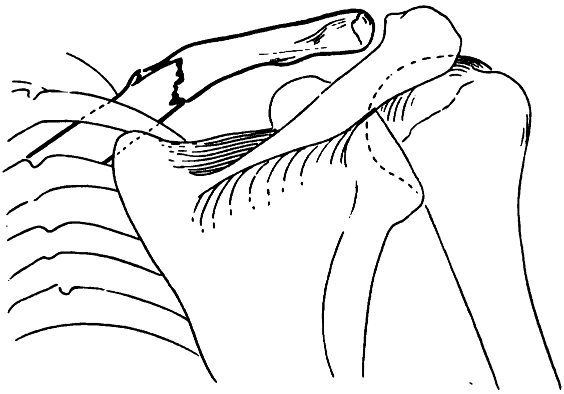


FIG. 115.—Complete fracture of the clavicle at the junction of the two curves seen from the rear. There is little angularity or displacement.

assumed a position parallel to the long axis of the humerus (see Fig. 117). It is unusual to find the outer fragment riding above or behind the inner fragment.

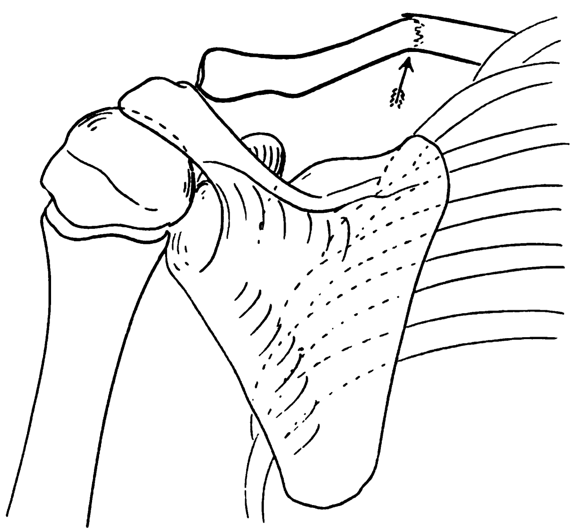


FIG. 116.—Fracture of the clavicle in a child. Seen from behind. Note the tendency to impaction.

Displacement of the fragments is influenced by the anatomy and the continuance of the action of the force after fracture is accomplished. The inner fragment is drawn upward by the attachment of the sterno-cleidomastoid muscle, or pushed by the outer fragment (Figs. 118 and

119), but its displacement is not great unless the rhomboid ligament which holds it to the first rib is ruptured. The outer fragment tends

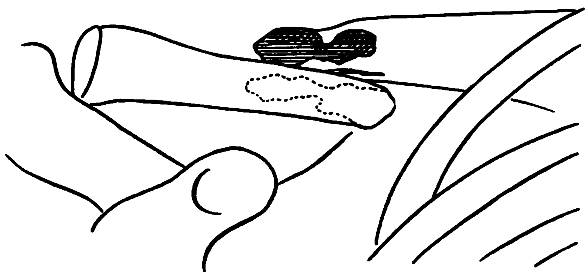


Fig. 117.—Usual displacement of fragments in clavicular fracture. Inner fragment drawn upward.

to be displaced downward, forward, and inward either in front of or behind the inner fragment according to the direction of the force and the type of the oblique fracture. This position is aided by the unsupported weight of the arm and the contraction of the pectoralis

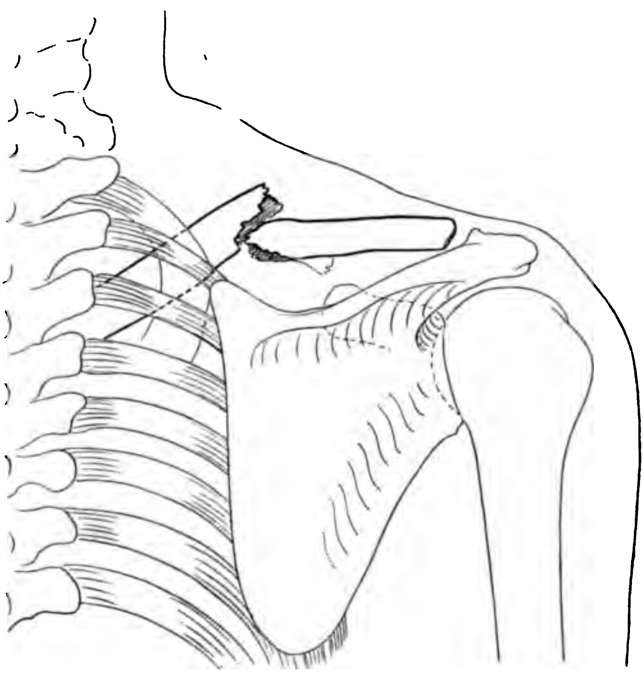


Fig. 118.—Usual displacement of clavicular fracture in an adult. Seen from behind.

major or deltoid muscles pulling the shoulder down and in when the clavicle support is lost. The scapula also tends to embrace the

thorax more closely when this support is lost, and the forward and inward position of the shoulder is favored that much more.

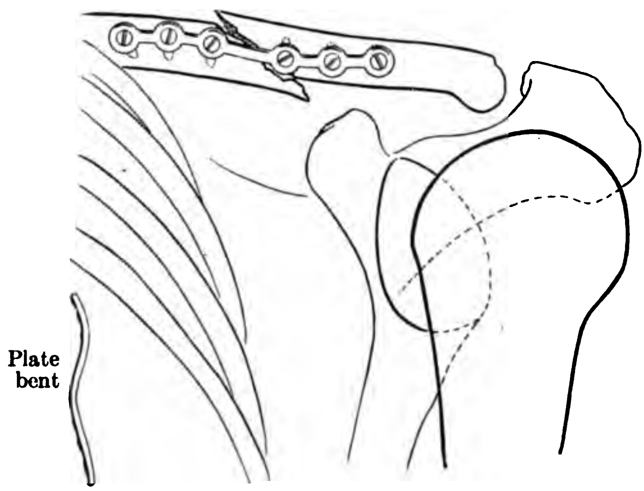


FIG. 119.—Repair of the preceding. Note the method of bending the plate before attaching it.

In transverse fracture the periosteum may not be completely torn, and the fragments remain in apposition but take on an angular deformity either up or down or forward or back.

In infants and children trivial falls result in bending and greenstick fractures which cause little displacement (Fig. 120). The patient has pain and does not use the arm, but the condition may be over-

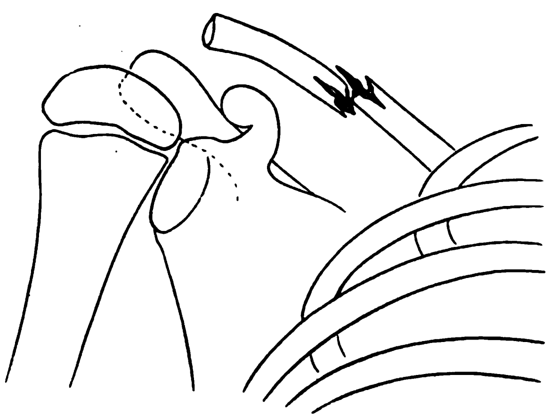


FIG. 120.—Complete fracture in a child. A small amount of displacement.

looked unless examination is thorough. Palpation may reveal a slight thickness or angular deformity directed forward and upward, and if

the fracture is complete there is distinct unevenness according to the usual displacement.

Fractures of the outer third, the acromial end (Fig. 121), are next in order of frequency and arise from direct violence from blows on the shoulder from above, or indirect violence received from falls on the arm when the arm is less abducted than in the mechanism of the shaft fracture. When the arm is closer to the chest, the humerus is driven more directly upward. This condition usually results in a transverse fracture between the conoid and trapezoid ligaments, and the displacement is very little, because both fragments retain their strong ligamentous attachment to the coracoid process of the scapula. If the line of fracture is inside of these ligaments, the inner fragment is displaced upward and forward with considerable separation (see Fig. 122).

FIG. 121.—Fracture of the acromial end of the clavicle. Displacement limited by ligaments. (See Fig. 122.)

A third type is found in fracture external to, or outside of, the trapezoid ligament. This injury is caused by direct violence applied at the shoulder. There may be no displacement at all because the conoid and trapezoid ligaments hold the outer piece in position. Ordinary displacement is angular. If the direct violence has been severe, the outer fragment is tilted downward, loosened from the acromioclavicular ligament and driven by the force it may lie at right angles to the rest of the bone. This type is difficult to replace by manipulation and often demands open operation.

Fracture of the inner or sternal extremity is unusual. It is caused by direct violence applied over the inner end or indirect violence from falls or blows on the shoulder when the arm is abducted and elevated. This violence usually results in dislocation of the sternal end. If the ligaments about the sternoclavicular joint hold, and the bone breaks, the line of fracture is generally transverse or oblique, and the displace-

ment is angular forward or forward and downward. This displacement is influenced by the costoclavicular (rhomboid) ligament, which holds the clavicle down to the first rib, overcoming any tendency to upward displacement from contraction of the sternocleidomastoid muscle. The direction of the force and the pull of the pectoralis and deltoid muscles may also pull the outer fragment down.

Separation of the epiphysis of the sternal end of the clavicle, which unites as late as the twenty-fifth year, may be included in fractures of the inner end. The condition is rare. Three cases were reported by Hutchinson.[1]

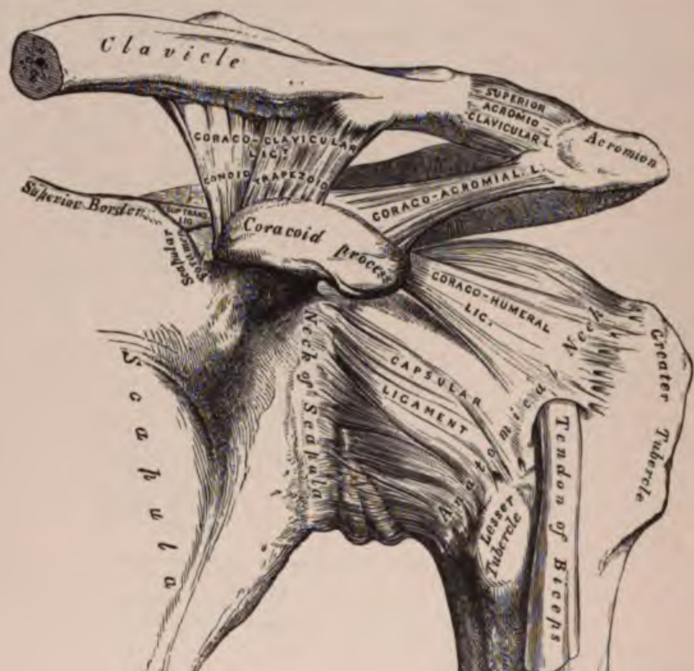


FIG. 122.—The left shoulder and acromioclavicular joints, and the proper ligaments of the scapula. (Gray.)

Complications.—Complications of fracture of the clavicle are rare. They consist of injuries of the brachial plexus nerves, which lie beneath and behind; of the subclavian artery and vein, or the internal jugular vein; puncture of the lung or opening of the pleural cavity by tearing of the upper extremity; or complications about the shoulder-joint from displaced fragments and interference with function. A few cases of brachial plexus paralysis, either primary from the contusion

[1] British Med. Jour., July 16, 1887.

of the injury, or secondary from the later callus pressure are reported. This possible complication should always be remembered. Aneurism of the subclavian, and arteriovenous aneurism, have also been recorded, but are very rare. The subclavian muscle and the periosteum, as well as the usual displacement of the fragments, protect the important underlying structures in the neck. Open and gunshot fractures and those accounted for by direct violence with great displacement are the ones followed by complications. Ununited fractures of the clavicle are relatively uncommon. They are usually accompanied by angular deformity and a distinct false joint, if of long enough standing. Function in the arm varies, but generally becomes fair. Pain after use or pressure symptoms of the large mass at the fracture site are found. Fracture of both clavicles simultaneously occurs when compression force is applied to both shoulders, as in lateral squeezes between car-bumpers, or as in the "death zone" between street cars passing in opposite directions. Stimson[1] mentions a case caused by a horse kick, a hoof being planted on each clavicle. If immobilization is considered inadvisable because of chest complications threatening the lungs or other contra-indications, non-union may follow the double fracture. Rest in a supine position generally takes the weight of the arms off the chest, helps the dyspnea, partially or completely reduces the deformity, and gives a good functional result. I do not believe that the loss of power in the accessory respiratory muscles has much influence on the dyspnea, because in fractures of the cervical spine with paralysis of all respiratory muscles except the diaphragm dyspnea is rare.

Symptoms, Diagnosis, and Course.—The symptoms of the common fracture of the shaft or middle third of the bone are pain, a characteristic attitude, loss of use of the arm, and apparent deformity in the clavicular area. Added to these the signs of crepitus and swelling with ecchymoses are nearly always present. The pain is present, both as localized tenderness over the site of fracture of the bone and as a result of attempts to move or raise the arm. The patient rests with the shoulder dropped downward, forward, and inward and there is a narrowing of the shoulder breadth from midsternum to the humeral tuberosities which form the outer margin of the shoulder region. The patient inclines the head toward the injured side to relax the muscles pulling the inner fragment upward, and with the uninjured arm supports the elbow to hold the shoulder up and to protect the broken bone from the jars of movement. Palpation or inspection reveals the overlapping deformity of the fragments, and crepitus is easily obtained, as is the false motility between them. When the overlapping is very marked, crepitus may not be obtained until the shoulder is drawn backward and upward and the fragments brought into line.

The loss of functional use of the arm is complete in the early hours after fracture and probably arises from the pain caused by the rubbing

[1] Fractures and Dislocations, 7th edition, p. 215.

of bone fragments when motion is attempted. The patient always feels relief when complete reduction is made and held and will then try to use the arm as much as the restriction of dressings allows. After healing of the fractures with overlapping, function in the arm is little impaired when use is continuously indulged in. Absence of the clavicle may result in a surprisingly good function of the arm. I have recently seen a young boy whose clavicle was completely resected for sarcoma. The periosteum was removed with the bone and no regeneration followed. After several months he returned for implantation of an autogenous bone splint to act as a clavicle, but the arm function was excellent and was progressing, so that it was decided not to submit him to a second operation when he could use the arm so well.

Infants usually cry and hold the head pressed over against the injured shoulder. Attempts to lift them by slipping the hands in the axilla cause pain, and examination can only be made when the child is placed flat on a table or bed and the head coaxed away from the flexed attitude. Fracture of the *outer third* is seen more often than that of the inner third. When the line of fracture runs between the conoid and trapezoid ligaments, there is little displacement. Pain and local tenderness are less than in fracture of the middle portion. The most reliable signs are a constant point of deep tenderness to pencil pressure and ecchymoses. It is possible in some cases to obtain crepitus through vigorous manipulations of the shoulder and through a pushing of the humerus upward. This procedure is painful and unnecessary. If the external fragment has been displaced downward, it may be felt, or its position may be seen. There is shortening of the shoulder breadth. Differentiation must be made from dislocation of the acromial end of the clavicle. In incomplete dislocation this is quite difficult, a roentgenogram often being necessary, if there is much swelling. The presence of crepitus, the greater pain located further in toward the midline in fracture, and a holding of the accomplished reduction of fracture are the main points of difference. Complete dislocation of the acromial end gives an apparent deformity with signs of fracture absent (see Dislocation).

Fracture of the *inner or sternal third* is very unusual. It is caused by direct violence or indirect violence from the shoulder region which causes dislocation of the sternal end. Line of fracture is transverse or oblique, with an occasional crack in the long axis of the bone. Displacement is usually not great. The outer fragment is held by the rhomboid ligament to the first rib, the inner fragment is held by the sternoclavicular ligaments. Additional factors causing the displacement are the untorn periosteum, the action of the pectoralis major and the sternocleidomastoid muscles, and the force of the shoulder weight bearing on the outer fragment. Whenever there is little displacement it is angular and downward. Where the two fragments are completely separated the sternocleidomastoid contraction dominates, and the outer fragment is pulled upward. This fracture has the symptoms and signs common to those of the middle third, all points moving in toward

the sternum. It must be differentiated from dislocation through crepitus and a deformity removed from the exact end of the bone. There is a tendency for the deformity to remain reduced in fracture, and roentgenogram decides the difficult cases. Separation of the sternal epiphysis previously mentioned must also be borne in mind.

The usual course of clavicular fractures is satisfactory. Within eight or ten days the lump of callus about the site of fracture can be felt, crepitus ceases, and union progresses rapidly. If the immobilizing dressing has confined the elbow-joint, this may be stiff for ten or twelve days after removal of the bandages. Freedom of motion quickly returns and becomes normal. After three and a half weeks the callus is firm, union is strong enough to permit an attempt at functional use of the arm suspended in a sling. Overlapping of the fragments is very common; good alignment should be the rule. If a fracture at the ends has been overlooked and the shoulder has not been immobilized, pain is more severe after five or seven days than it was at the time of injury. The general prognosis is good, even with marked deformity. The shortening of the shoulder breadth is often compensated by some lateral curvature of the spine and an apparently bad deformity with overlapping does not mean great loss of function. Large callus and failure of union are rare. The usual disability in favorable cases is ten weeks before complete return of power and use in the affected arm.

Treatment.—Treatment of fractures of the clavicle is divided into: *A*, non-operative, which includes (*a*) recumbent and (*b*) ambulatory of both adults and children and *B*, operative.

The first step in treatment is to restore the shoulder from its position of displacement downward, forward, and inward to its normal level and distance from the neck. This insures the corresponding normal position of the shoulder-joint and arm and of the scapula, which must be rotated backward and carried upward until it resumes its former suspended position over the dome of the chest. For the obtaining of this correction reduction of angular deformity or overlapping of the bone fragments must be accomplished, the normal alignment must be resumed, and the position must be maintained until bony union is strong enough to hold unaided. The various methods of treatment which have been in use for centuries have aimed at these results, but no one line of care has fitted all cases or led to perfect results. Most important of all is the necessity of swinging the scapula backward to its position and at the same time elevating it. This result is difficult to get and to hold, especially if the patient is ambulatory and the weight of the shoulder and arm counteract the correction of the dressing. Reduction is usually not difficult. In fracture of the shaft, for example, an assistant stands on the injured side slipping one hand over the shoulder, pulling it backward and outward to rotate the scapula into position, while with the other hand he pushes up on the elbow to raise the scapula. At the same time the surgeon, standing in front or leaning over the seated patient from behind, manipu-

lates the fragments by direct pressure until they are brought into alignment. If difficulty is experienced in making reduction by this means, the surgeon may place his knee between the shoulder-blades and pull on the two shoulders, or draw the arm upward and outward against counter-extension made on the side of the neck. These expedients are not often necessary, and they will fail to obtain reduction in some cases of marked displacement of the outer fragment. Some displacements will yield to mild measures, especially a prolonged recumbent position, while others demand open operation. The important consideration is to maintain the correction during and after the application of the permanent dressing, and yet more important is it to *over correct* the deformity so that the shoulder is changed from a position of displacement downward, forward, and inward to one of elevation and outward rotation in which the scapula hugs the chest wall posteriorly, and is on a level above the bone on the injured side. Different permanent dressings have been advised for fulfillment of these requirements; the important ones will be described. Some operators accomplish the elevation of the shoulder by placing the hand across the chest and pushing up on the elbow, while others effectually hold the shoulder outward and possibly backward, but fail to obtain elevation.

A. Recumbent Treatment.—This treatment is based on keeping the patient in bed and allowing the weight of the shoulder to overcome the deformity unaided or by means of pads. The older and simpler method consists in having the patient lie flat on a hard, non-sagging mattress. The arm is lightly bound to the side, or is pushed upward by counter-extension applied by a band passing under the axilla and attached to the head of the bed. The head is slightly flexed toward the injured side that the neck muscles may relax. This treatment confines the patient to this position constantly until firm callus has formed and is a very irksome restraint. It may be supplemented by a narrow pad of sufficient thickness placed between the shoulder-blades along the spine, which will permit the scapulæ to fall farther back in outward rotation. Straps or pads may be placed over the site of fracture for help in maintaining reduction.

Modern modifications of the recumbent position contemplates using the whole weight of the arm hanging freely over the side of the bed to effect reduction. The patient is placed in a horizontal position so that the arm on the side of the injured clavicle hangs down perpendicularly over the edge of the bed and the body is held from slipping by a broad muslin swathe which holds it to the opposite side. The forearm may be supported by a sling to the side of the bed as suggested by Goutrand,[1] or Couteaud's position may be adopted. This means that the perpendicular suspension of the overhanging arm is kept for a sufficient length of time to permit reduction of the fragments. This may require but a few hours, and if there is much pain,

[1] Bull. et Mem. de la Soc. de Chir., xxxiii, 644.

a few c.c. of a 1 per cent. novocaine solution are injected about the site of fracture. When reduction is satisfactory, the forearm is bent at a right angle and supported on cushions, the arm alone furnishing sufficient weight to maintain reduction, but the greatest care must be exercised against movement. Oudard[1] has reported enthusiastically on this treatment and advises that a third position be selected after ten or twelve days for patients who cannot endure the hanging condition. This consists in laying the whole arm alongside the body as in older recumbent methods without disturbing in the slightest the reduction gained. The bed treatment is continued for about four weeks, after which the patient is permitted to get up with the arm in a sling, and after ten days, active movements of the arm and shoulder follow.

Results by these methods are uniformly good, because the callus is small and the reduction nearly perfect. Fractures of both clavicles can be treated best in this way unless there are complications which prohibit the supine position. Young girls or women who dread overlapping deformities of the clavicle are treated thus. I have seen the method applied satisfactorily to a laborer with a deformity impossible to reduce otherwise. Obviously children cannot be cared for in this manner. Continual digital pressure to hold reduction by relays of attendants hardly deserves mention. I have never seen it used.

B. Ambulatory Treatment.—This treatment is the one most frequently applied and is the only non-operative treatment which can be used on children. The indications for replacement of the shoulder in a normal position are met completely by few of these ambulatory appliances. They may be enumerated as axillary pads, figure-of-eight bandages to draw the shoulder backward, wooden or plaster cross splints on the back, against which the shoulders are bandaged in corrected position, or large mattress-like cushions used in a similar manner. Other splints are applied anteriorly to hold the shoulders back. Various bandages and swathes or adhesive dressings are used, including Velpeau's, Desault's and Sayre's with its many modifications.

Large axillary pads which act like a fulcrum to force the shoulder outward when the arm is bound to the side have little practical use because of the amount of pressure needed. This will interfere with circulation in the arm or make pressure on the brachial nerves, and the accumulation of sweat in the axilla, even when the pad is covered with sterile absorbent material, necessitates frequent renewal and movement of the fracture. The pad is used in connection with Desault's dressing. Figure-of-eight bandages applied around each shoulder and arm pit and across the back pull the shoulders outward and backward but do not raise the scapula. Their greatest fault does not lie so much in failure to elevate the shoulder as in the constricting pressure on the axillary structures and arm and the chafing of the skin. This defect can be partly obviated by the application of a large

[1] Caducee, 1914, xiv, 119.

pad of saddlers' felt over the front of the shoulder, but the dressing becomes unstable and irritates. Figure-of-eight plaster of Paris is sometimes used over heavy pads. Peckham[1] uses webbing straps stiffened with whalebone and covered with cotton flannel. These

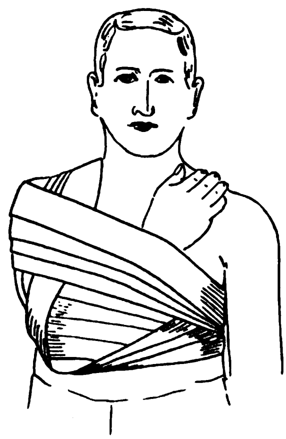


Fig. 123.—Velpeau's bandage for fracture of the clavicle completed.

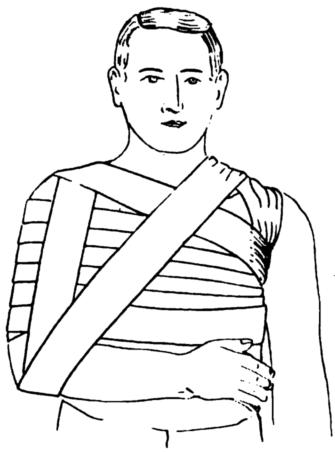


Fig. 124.—Desault bandage to support the arm without a sling around the neck to the wrist.

pass around the shoulders and are laced together snugly behind. The difficulty with these bandages is the keeping of them out laterally toward the point of the shoulder.

Velpeau's bandage is made of several three-inch muslin rollers which are applied to the injured shoulder after the axilla and contact area

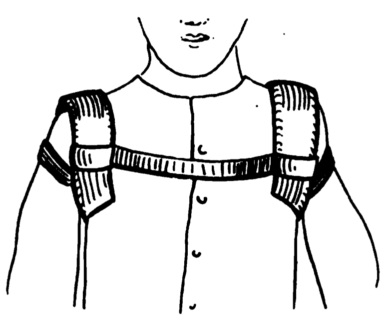


Fig. 125.—Peckham's webbing straps for dressing fractured clavicle.

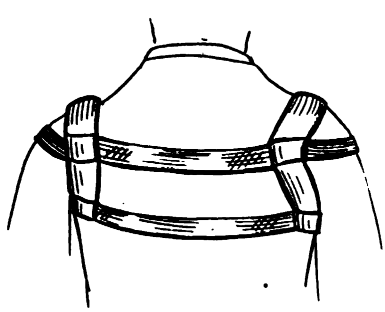


Fig. 126.—Rear view of Peckham's dressing.

of the chest and forearm have been bathed in alcohol and aseptically padded. The hand of the injured side is placed on the opposite shoulder and successive turns are made over the shoulder and across the

[1] Boston Med. and Surg. Jour., clxvi, No. 21; and ibid., clxx, 651.

back and around beneath the elbow to immobilize and support the arm and shoulder. This dressing is objectionable in that the forearm and hand are bound down tightly and cannot move, the scapula is

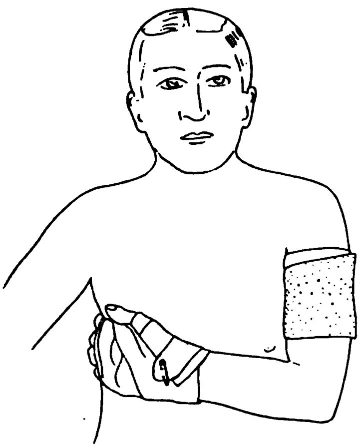


FIG. 127.—Sayre's adhesive dressing, first strip applied.

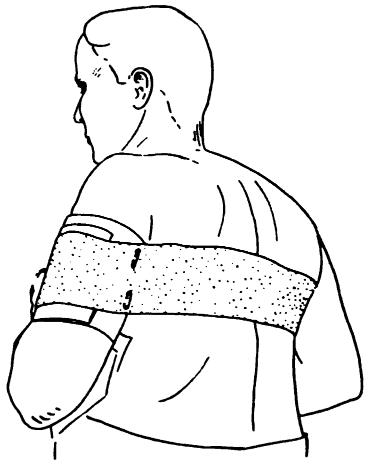


FIG. 128.—Side and back views of first strip of Sayre's dressing.

not raised by it, and all the indications for treatment are not met. It becomes loose, and forearm motion works the arm out of its support, so that it must be reapplied frequently.

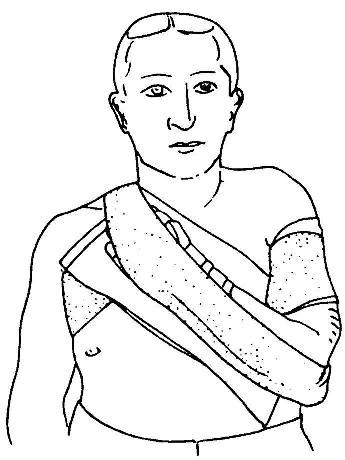


FIG. 129.—View of the completed Sayre's dressing. Note the pad beneath the forearm over the chest.

Desault's is really an excellent means of fulfilling the requirements of reposition after fracture of the clavicle, if it is applied correctly. The bandage consists of three parts: The first holds a large pad in

the axilla by multiple turns about the upper chest. The second part passes around the chest and the injured arm causing some pressure inward of the elbow against the trunk, using the axillary pad as a fulcrum to push the shoulder outward. This endeavor has doubtful value, as previously mentioned, because an efficient pad would doubtless cause untoward pressure on the brachial structures. The third part of the bandage aims to elevate the injured shoulder by holding it up suspended on the neck and shoulder of the well side. The forearm and hand are left free to be suspended by a light neck sling.

Sayre's dressing is probably the best routine treatment of fractured clavicle in adults. It consists of two pieces of surgeon's adhesive plaster—the mole skin plaster is the best—three and a half inches wide. The first piece is applied over a folded pad or towel about the arm on the injured side just below the axilla. The plaster does not encircle the arm; a space is left in the circumference on the rear and inner surface where the plaster makes a loop and is held by a safety pin or its own sticky surface. The free end of this arm band passes around the back under the opposite axilla half-way around the front of the chest and serves to hold the arm outward and backward to rotate the scapula into contact with the chest. The second piece is applied like a scarf, holding up the arm on the injured side by supporting the elbow, the weight of the arm being supported by the well shoulder. A hole is cut out of the plaster at its point of application over the elbow and a small pad covers the olecranon. By this means the shoulder and scapula are pushed up and backward as high as desired and the free ends of the adhesive covering the flexed forearm are overlapped on the opposite shoulder. It is necessary in this dressing, as in all dressings where skin surfaces come in contact, to pad well. The third part of the Desault bandage may be applied over the Sayre dressing to give added firmness. The skin will not tolerate this dressing more than ten or twelve days, and it must then be removed, the surfaces washed with alcohol, and a new dressing applied. Many modifications of this dressing have been suggested, generally aiming to allow some freedom of the forearm and hand by leaving them out, or only partly including them in the second piece, but any looseness of the hand or forearm which permits motion tends to defeat the purpose of the dressing and spoils its efficiency. To avoid the irritation of renewal of the plaster, Collins[1] has suggested fixing a lacing in the two pieces fastened through eyelets made in the adhesive plaster. The slack of stretching adhesive or looseness from movement of the arm may be taken up by tightening the lacing.

The objections to Sayer's dressing are that it is very uncomfortable to wear the hand immobilized against the chest with possible constriction of the arm. The back pull is on the arm instead of on the shoulder where it should be. The adjustable modifications eliminate one objectionable feature (Figs. 130 and 131).

The so-called abduction treatment meets many of the indications

[1] Ann. of Surg., lv, 88.

for correct reposition. Moorhead[1] has noted that in order to accomplish the essential point in treatment of pushing the shoulder up and out it is necessary to abduct the arm to or beyond a right angle. The farther the arm is pulled back after abduction, the easier it is to correct the overlapping. The technic of application of the plaster cast after this reduction is as follows: The patient sits on a stool with elbows bent to a right angle, both arms are grasped and elevated to or beyond a right angle and the raised elbows are then pulled farther back until the overlapping is corrected and the fragments are in line. The body and affected arm are protected by flannel and a body plaster cast is applied with a spica over the shoulder. The unaffected arm is

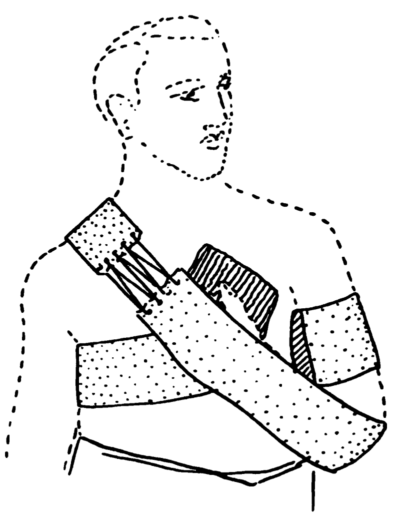


FIG. 130.—Collins's modification of Sayre's dressing with eyes and lacing for adjustments without removing the adhesive plaster.

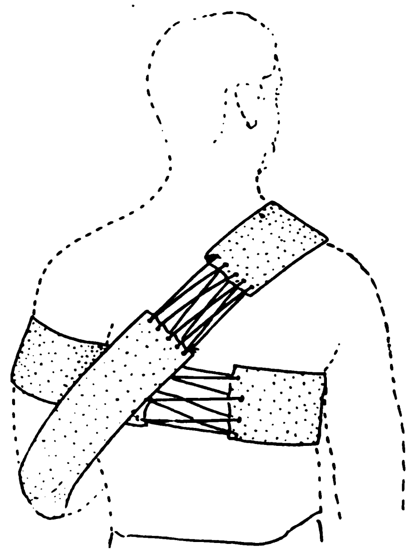


FIG. 131.—Back view of Collins's dressing.

left free. The cast can be reinforced with strips of wood and is left in position for three weeks, after which the callus has developed and the arm can be put in a sling[2] (Figs. 132 and 133).

Infants and children very frequently sustain green-stick fracture. It is best to administer a small amount of general anesthesia and press the deformity back into normal alignment, using precaution not to

Post-Graduate New York, 1914, xxix, 831.

[2] References for fractured clavicle: Leland, Jour.-Lancet, February 15, 1913; Hessert, Surg., Gynec. and Obst., February, 1910; Watson, Jour. Am. Med. Assn., February 6, 1910, Barrell splint; Brumwall, Jour. and Lancet, October 15, 1910; Nydigger, Jour. Am. Med. Assn., July 3, 1909; Bellantoni, New York Med. Jour., December 12, 1908; Bellamy Russel, New York Med. Jour., April 13, 1907; Hartshorn, New York Med. Jour., 1914, c, 1110; H. L. Taylor, Pediatrics, December, 1899; Bardenheuer, Fracturen der Clavicula, die Techn. des Extensions verbanden 37, 1905.

overcorrect the clavicle and separate the fragments. The child's skin is carefully washed with alcohol, a simple desiccating or toilet powder is applied, and the arm is bound to the chest by a broad washed muslin band which is pinned snugly up the front. The forearm and hand are free and are supported by a light sling about the neck. The band is removed every other day for the inspection and cleansing of the skin of the chest and arm, and powder is reapplied. In three weeks, if the callus reaction has been satisfactory, the band can be left off and the arm held in a sling for a week and a half longer. Passive motion of the elbow and shoulder can be given when the band is removed for bathing, and the forearm can be massaged every day. In some fractures in childhood it may be impossible to correct the bowing of the bone. Complete fracture with separation of fragments usually calls for the Sayre dressing, and unusual precautions must be taken to avoid skin irritation in the young patients.

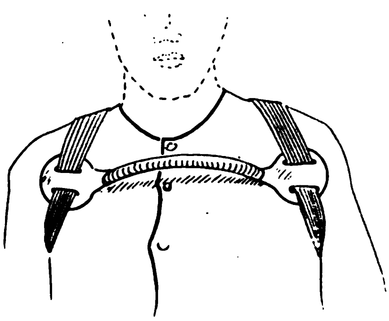


FIG. 132.—Fayette Taylor's dressing for fractured clavicle. The arched band is metal.

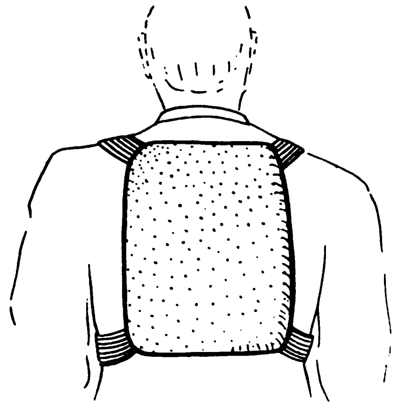


FIG. 133.—Rear view of Taylor's dressing, showing the large pad used over the scapulæ.

B. Operative treatment is used for certain indications. These are ununited fracture, recent fractures which are irreducible or which have injured or threatened bloodvessels and nerves by pressure, and certain cases of great comminution or multiple fracture. Simultaneous fractures of both clavicles should also be operated on. The easy approach to the clavicle because of its subcutaneous position has made it one of the first bones to be subjected to operative treatment. This same subcutaneous position has caused many infections and disappointments in results.

Special technic of operation on the clavicle involves but a few points. The incision can be curved with base upward so that a wide flap of skin and platysma must be reflected before the bone comes into view. This is better than an incision in the long axis of the bone just above, because it furnishes better covering for the field of bone work.

If silver wire or kangaroo tendon is used to hold the replaced fragments, it is introduced through drill holes a trifle removed from the ends of the bone The operator must use the drill cautiously to avoid injury of the subclavian vessels. Fractures of all parts of the bone have been plated. It would seem unnecessary to warn the operator not to attempt to apply a straight Lane plate to this curved bone, but I have seen it attempted several times. After the deformity is corrected the plate must be moulded by being bent with heavy forceps to the proper curve (see Fig. 119). It can then be screwed into place to fit perfectly. If this precaution is not taken, the operator may expect to find when postoperative roentgenogram is made, that most of his screws are not holding in the bone at all. Inlay transplants of bone are not often indicated in fresh fracture, unless there is great comminution of a part of the bone. For that purpose a curved portion of a rib may be utilized.

Results of operative treatment in fresh fracture are not eminently satisfactory. Wire and kangaroo tendon will not hold perfect apposition *unless the external dressing is applied and kept on as in unoperated cases.* One must *not* trust to the internal splint at all. On the whole, kangaroo tendon gives the best results, because infection seldom follows and the suture does not need removal. Wires are removed in practically all cases. I believe it is advisable in some cases to bring the wire out through the skin after operation and remove it from the bone as soon as callus is sufficiently formed. That should be within two weeks, the skin wound being aseptically bandaged and the wire flooded daily with tincture of iodine. All Lane plates I have ever seen put on the clavicle have been removed for infection or irritation, but the bone generally heals quickly.

Ununited fracture may lead to no symptoms of pain or decreased function. One case of ten years' standing which I saw refused any treatment, on the ground that there was nothing to treat, as the man said he could use his arm as well as he wished and there was no pain in the false joint in the bone. A large amount of callus around the site of a non-union may lead to a clinical diagnosis of sarcoma and pathological fracture. Treatment consists in freshening the bone surfaces, removing adventitious bursæ or pseudarthroses, and approximating the fragments. Increased shortening of the clavicle may result. If the bone ends are attenuated and absorbed, the transplant may be attached so as to maintain the length present by bridging the bony gap instead of allowing the shortening which follows the approximation of the freshened ends. Edington[1] treated one case after a wiring operation ten months before. He found a thick fibrous wall surrounding a small cavity in which the end of the wire lay. Autogenous grafts may be tied to the clavicle fragments by wire or by kangaroo strands and should lead to bony union. I have operated on one case with good result and seen one other. I have lost the record

[1] Glasgow Med. Jour., 1914.

of a third case of which I have recently read. An ununited fracture of a year's standing was treated by attaching of the ends. After twenty-seven days the graft was displaced and necrosed through the skin and was removed. After a week, blood injections were given weekly for a month according to Beir's method, 15 to 20 c.c. at a time. An excellent union followed.

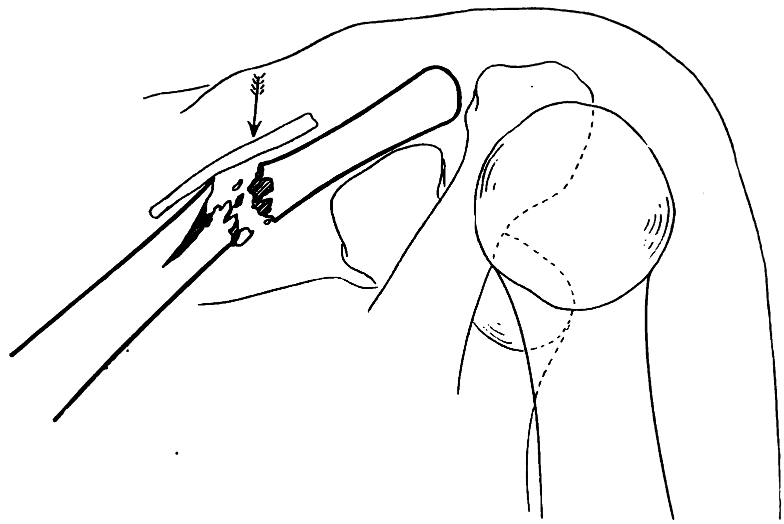


Fig. 134.—Repair of fractured clavicle with loss of bone substance by a bone transplant bound on.

DISLOCATIONS OF THE CLAVICLE.

1. Dislocations of the sternal end, forward, upward, inward or inward and backward. Subluxations.

2. Dislocations of the acromial end, complete and incomplete. Supra-acromial, subacromial and subcoracoid.

3. Double dislocations and complete dislocations, both ends of the bone simultaneously.

The reader is referred to the remarks on dislocations of the shoulder region in the chapter on Fractures and Dislocations of the Humerus.

1. **Dislocations of the Sternal End of the Clavicle.**—Bardenheuer[1] found in six and a half years at the Berlin University Clinic that there were 400 dislocations, 16 of which were of the clavicle. I have reviewed a series of 775 dislocations at the Cook County Hospital in about the same period of time and find that there were 73 dislocations of the clavicle. This makes their frequency about 9.4 per cent. of all dislocations.

The sternal end is displaced much less often than the acromial end. The sternoclavicular joint is an arthrodial articulation permit-

[1] Dislocations of the Upper Extremity.

ting motion in nearly all directions, and the component parts are the sternal end of the clavicle, the upper and lateral surface of the manubrium sterni, and the first rib cartilage. The articular end of the clavicle is larger than the notch of the sternum in which it rests, and between the two is the articular disk of cartilage which is fastened below to the first rib. Binding this joint and giving it firmness are the ligaments, for the schematic representation of which see Fig. 135. The short sternoclavicular ligaments, anterior and posterior, and the interclavicular ligament steady the joint, but on its upper and lower surface are the weak points. The costoclavicular or rhomboid ligament is the strongest factor in preventing posterior displacements of the clavicle. The anatomical construction of the joint has less to do with its dislocation, if we except the unguarded upper portion, than relaxation of the joint and the direction of the force applied to cause

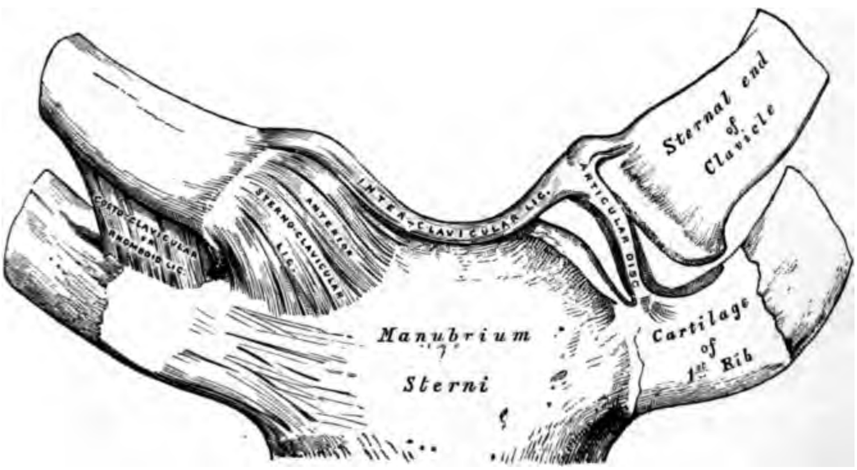


Fig. 135.—Sternoclavicular articulation. Anterior view. (Gray.)

the displacement. This joint is the articulation of the shoulder girdle with the trunk, because the clavicle carries the scapula with it in all movements, the latter bone moving over the surface of the chest. Movements of the shoulder when it is elevated or depressed are transmitted to the sternal end of the clavicle and take place between the end of the bone and the articular disk, and forward and backward shoulder motions are transmitted between the articular disk and the articular surface of the sternum. Consequently elevation of the shoulder is checked by the rhomboid ligament and depression by the articular disk with the help of the interclavicular ligament and the first rib beneath. Sternal end dislocations are in any direction and are divided clinically into forward, or presternal, upward, and backward or inward.

Presternal dislocations are the most common, representing from 1

20

to 1.5 per cent. of all dislocations of the body, according to Meyer.[1] Krönlein found 5 sternal dislocations in a series of 400 dislocations. They are caused by pressing the shoulder backward or pulling it backward and outward. Pressure downward on the outer end of the bone also helps cause the inner end to be sprung out of place, or is a sole cause. The ordinary causes are falls on the point of the shoulder, falls on the extended arm and hand, or forcible jerks and pulls on the shoulder. I had one case caused by a man slipping on a ladder, his arm extending between two rungs, with his body weight so suspended that the pull tended to carry the shoulder backward and upward, and the clavicle gave way at the sternal attachment. The sudden strong pull of the arm and shoulder as a whole exerts its full tension on the point of articulation with the trunk. The clavicle is pulled back beyond its limit of motion, and as the ligaments at the sternoclavicular joint give, the first rib beneath probably acts as a fulcrum to raise the sternal end forward out of its articulation. Rarely there are other causes from pathology in the chest and sternal region. Lateral squeezes of the shoulder have caused simultaneous dislocation of the sternal end of both clavicles, and the traumatism of birth has produced dislocation in the infant. Aneurism of the aorta, spinal caries with deformity and violent inspiratory efforts may be enumerated as other causes.

Pathology.—The condition may be a subluxation or a complete dislocation. In the first-named class the bone is partly raised out of the sternoclavicular joint, the edge of the bone or the cartilage impinging against the sternum. The anterior sternoclavicular ligament may be merely stretched, but more often it is shredded in part of its width and the posterior and rhomboid ligaments remain intact. If the bone is completely dislocated, its end comes to lie on the lateral or front surface of the sternum, or if the shoulder has been pulled violently backward and upward, the sternal end of the clavicle takes a forward and downward displacement of one or more centimeters. In one case on which I operated the anterior sternoclavicular ligament was torn irregularly across, permitting the bone to slip forward. The tags did not interfere with reduction in any way, and the posterior ligament was not ruptured. Complete dislocation with displacement may rupture both the posterior and rhomboid ligaments, or they may remain attached to the periosteum, which is stripped up to permit the bone to escape from the articulation. Secondary displacement from muscular pull can be expected when all ligamentous support is lost at the sternal end of the clavicle. The sternocleidomastoid is usually relaxed by posture, and the pectoralis major may pull the bone downward. Dislocations caused by shoulder changes follow after distention and stretching of the capsule and ligaments, so that an incomplete dislocation might be found with no capsular tear. The complications are few. Hemorrhage is usually local and small in

[1] Deutsch. Ztschr. f. Chir. Leipsig, 1912, cxix, 497.

amount. An inflammatory bursitis may result from the trauma. I had one case which proved fatal ten days after injury because of traumatic pneumonia. Dislocation of the other end or fracture of a portion of the sternal endof the clavicle may accompany this dislocation.

Symptoms and Diagnosis.—Incomplete dislocations are often overlooked either because serious rib fractures accompany them, or the displacement is so slight that it is not noticed. After a couple of days the hematoma at the point of separation, the persistent pain and tenderness to pressure directly over the joint, and the slight deformity compared with the joint on the other side, will make a diagnosis. Complete dislocations are apparent through inspection and palpation. The sternal end of the clavicle rides in front of the sternum; there is pain and deformity. Crepitus is absent, and the displacement is easily reduced, to recur on the slightest movement of the arm. The shoulder drops a little, and the head is bent toward the affected side. Use of the arm is at first very painful and is restricted. After a few days when the pain subsides more functional use results. The dislocation must be differentiated from fracture of the sternal end of the clavicle. Fracture is farther out toward the acromial end, there may be an angular displacement or crepitus, and if the fracture shows displacement the outer end of the inner fragment tends to tilt upward and can be palpated. Shortening of the long axis of the clavicle is not of much help, and in cases of fracture with little displacement, the roentgenogram will decide.

Reduction and Treatment.—The integrity of the joint depends on the ligaments, and when they are ruptured there is nothing to hold the bone in place. Reduction is easily accomplished by the surgeon's drawing the shoulder outward and backward to elongate the distance from the shoulder to the sternoclavicular joint and then pressing down on the sternal end of the clavicle. It may suffice to draw the shoulder outward, the bone slipping readily into the joint and immediately coming out when the shoulder is released. Stimson[1] mentions that the anatomical relation would suggest that reduction could be held by a holding of the shoulder forward by means of a figure-of-eight bandage crossing in front of the chest, which tends to press the sternal end into the sternoclavicular joint. A Velpeau or Desault dressing described under Fracture of the Clavicle may hold the reposition, or a broad piece of adhesive may be strapped over the joint across chest and shoulder to hold the reduction, the arm being immobilized through being bound to the chest. Danielsen[2] has carried the idea of forward position of the shoulder to maintain reduction to its logical conclusion. He advises that after reduction the arm should be raised until it is in contact with the cheek and the forearm is flexed over the head and held there. This forces the clavicle inward and fixes it firmly in the sternoclavicular joint so that it cannot escape. One case which he treated thus gave a prompt cure.

[1] Fractures and Dislocations, 7th edition, p. 590.
[2] Centralbl. f. Chir. Leipzig, 1914, xli, 1561.

The only other practical treatment is operative. The joint is approached by a semilunar incision with the base upward. The lacerated anterior ligament is found, the deformity reduced, and the ligament sutured over it. A near-by flap of periosteum or fascia may be used to strengthen this, or a transplanted piece of fascia lata may be used to reinforce it. I have nailed one case through the sternal end of the clavicle into the sternum after reduction.

Treatment by immobilization of the shoulder and arm when used simply or postoperatively, lasts four to six weeks. Meyer[1] recommends movements of the arm and shoulder within a week after operation and all movements in three weeks. Use of the arm progresses slowly for fear of retearing of the ligaments and renewal of the deformity. If recurrence ensues and the dislocation becomes habitual, Stimson's method of injection of alcohol about the joint may set up enough irritation to produce a fibrous ankylosis and good function. This type of case can be operated on and fixed by an ivory peg or nail after freshening of the bone end.

The prognosis is good for ultimate functional use after the dislocation has been reduced and retained. The joint is nearly always permanently enlarged. If reduction has not been complete, the deformity is more noticeable, but use of the arm is satisfactory except in those cases of recurrent dislocation which slide in and out and cause much pain.

Upward Dislocation.—This type is rare. It is caused by a depressive force acting on the shoulder and outer end of the clavicle, and the upper weak portion of the capsule at the sternoclavicular joint is burst through. If the dislocation is complete and the bone is forced out of the joint, the mechanism is probably caused by the first rib's acting as a fulcrum to the force pressing down at the lateral end. The sternal end of the clavicle tears away from all ligamentous fastening and rises up behind the sternal insertion of the sternocleidomastoid muscle and is pushed farther inward and upward by a continuance of the force. It may press against the trachea, causing dyspnea. The meniscus probably remains adherent to the clavicle. Associated injuries, comprising fracture of the ribs or sternum and fracture of the spine, may cause death. Stokes,[2] quoted by Stimson, described a case in which the dislocation was forward and upward and each sternoclavicular joint was so loose that the sternal ends of the clavicle could be moved in any direction. Autopsy revealed greatly stretched and elongated sternoclavicular and rhomboid ligaments. A case has been recorded by Baldwin.[3] This was an upward dislocation in a four-year-old girl which it was not possible to reduce, but as the deformity was not great and the function promised to become excellent, no open operation was performed.

Symptoms and Diagnosis.—Subluxations upward are difficult to recognize. There is slight displacement, the long axis of the clavicle is directed upward when compared to the opposite side, and there is

[1] Loc. cit. [2] Dublin Med. Jour., 1852, xiii, 459.
[3] West London Med. Jour., 1915, xx, 42.

local pain and tenderness. Complete upward dislocation may be determined by palpation and inspection. If the trachea is pressed upon, dyspnea may be alarming. Movements of the shoulder and use of the arm are inhibited, because each change of position is transmitted to the inner end of the clavicle and causes pain.

Treatment.—The shoulder is drawn upward and outward and the sternal end of the clavicle is simultaneously pressed downward into the joint. This may be held by an adhesive strap applied snugly over a pad placed on the joint. Reduction is not often difficult, unless the sternal end becomes entangled in the insertion of the sterno-cleidomastoid muscle, but maintenance is as uncertain as in presternal dislocation. The recumbent position with the arm at the side as used in fracture of the clavicle may be tried, with the interscapular pad added. Depression or drooping of the shoulder must be avoided if ambulatory treatment is used, because this renews the deformity. The Velpeau and Desault dressings may be used. Operative treatment should be applied to irreducible cases or to those with severe pressure symptoms. The insertion of the sternocleidomastoid can be divided and the bone replaced, held by a musculofascial flap or by external dressing.

Prognosis.—The prognosis as to function is good.

Backward Dislocation.—Backward, and backward and inward dislocations of the sternal end of the clavicle are the rarest forms of inner-end dislocations. The important costoclavicular and the interclavicular ligaments resist this form of dislocation. It is caused by direct violence transmitted by a blow or a fall on the chest when the sternoclavicular joint is relaxed. Indirect violence may also cause the dislocation by pressing both the shoulders together forward and inward, or by pressing one shoulder forward and dragging the other backward. The side of the chest opposite to the dislocation together with the sternum must be fixed in a steady position. This condition permits the transmitted force in the clavicle to burst the posterior capsule and ligaments and force its way behind the sternum. Usually this state of affairs is supplemented by force pressing downward at the sternoclavicular joint. Haehner[1] reports a case in a cavalry officer brought about by a fall forward on his saddle. In 1856 Malgaigne[2] collected 11 cases, and Haehner found 9 more, making 20 in all. Velpeau, Hotchkiss,[3] Geissler,[4] Delattre,[5] Poland,[6] and Bennet,[7] 3 cases. Of the 20 cases collected by Poland, 13 were due to indirect and 7 to direct violence. Hotchkiss's case had the clavicle dislocated in front of the sternum on one side and behind on the other.

Pathology.—The meniscus probably remains attached to the sternum, and the end of the bone is displaced inward, or backward and

[1] Deutsch. Ztschr. f. Chir., Leipzig, 1914, cxxx, 423.
[2] Knochen Brüche, Verrenkungen, Bd. ii.
[3] Jahresb. f. Chir., 1896.
[4] V. Leuthold Gedenkschrift, 1906, Bd. ii.
[5] Zentralbl. f. Chir., 1907, No. 50.
[6] Lancet, July, 1884.
[7] Jahresb. f. Chir., 1897.

inward, and is found between the sternothyroid muscle and the sternum. The posterior sternoclavicular and the interclavicular ligaments are torn, and the sternohyoid muscle is either stretched or torn from its insertion in the posterior ligament of the joint. Although this portion of the neck is crowded with important anatomical structures, injury to them is rare. The bone may press against the trachea or esophagus and cause dyspnea or dysphasia. Emphysema from lung puncture and fracture of the ribs may also result.

Symptoms and Diagnosis.—On inspection the deformity is easily noted. The sternal end of the bone is lacking in its customary position and cannot be felt, but the joint surface of the sternum can be palpated. The acromial end of the clavicle seems displaced forward, and it appears shortened. There is dyspnea, sometimes loss of pulse on the affected side, hiccough, and pain in the joint. If there is pressure on the vessels, venous congestion of the face or arm may be present. The arm is held rigidly and there is great pain on the slightest motion and a feeling of suffocation and anxiety which inhibits the use of the arm.

Prognosis.—The prognosis depends partly on the complications. If the injury is simple and reduction is easy, there should be little permanent deformity and less difficulty in maintaining reduction than in forward dislocation. Pressure of the head of the bone on blood-vessels, trachea, or nerves may demand operative interference, or lead to late consequences of an unfavorable character. Fixation in the dressing for a too brief period leads to a bulky thickening of the joint and prolonged weakness and uncertainty in the use of the arm. The tendency to recur is not great, and end-results after several months are fair.

Treatment.—The shoulder of the affected side is drawn backward and outward, and reduction is usually easy. Traction on the arm with the first rib as a fulcrum can be tried. Haehner's case yielded to this treatment, and a bandage holding the arm to the side prevented recurrence. The shoulder should be fixed outward and downward by an adhesive dressing, which should immobilize for at least three weeks. Rest in bed is excellent. Heller[1] reported a case on which he operated, strengthening the capsule with a transplant of fascia and fixing with catgut.

2. **Dislocations of the Acromial End of the Clavicle.—Anatomy.**—The acromioclavicular joint is also arthrodial and is surrounded by the capsular ligament strengthened by the superior and inferior acromioclavicular ligaments, an articular disk of cartilage and the coracoclavicular ligament. This latter ligament does not anatomically enter in the joint formation, but it is a very important structure in acromial dislocations of the clavicle. It is divided into two fasciculi; the one lying anteriorly and laterally is the trapezoid ligament and the one lying posteriorly toward the median line is the conoid ligament (see

[1] Zentralbl. f. Chir., 1914, No. 11.

Fig. 122). The articulation is oblique or slanting, and its surface is flat. The clavicle lies on a slightly higher level than the acromion.

Motion in this joint is of two kinds: a gliding of the outer end of the clavicle on the acromion and a rotation forward and backward of the scapula on the clavicle, the rotation being limited by the trapezoid ligament forward and the conoid ligament backward. This means that the scapula has more independence than the clavicle, which is really passive in its transmission of the shoulder-girdle motions to the trunk. When the acromioclavicular joint is made rigid, the pivot of motion of the upper extremity is carried to the sternoclavicular joint as previously described. As the shoulder is carried forward the angle between the clavicle and scapula is closed, and the trapezoid ligament is put on the stretch to limit the closure. In a similar manner, when the shoulder is moved backward, the scapuloclavicular angle opens to embrace the increasing curve of the thorax, and the conoid ligament holds to stop this spreading. These observations can be verified by cutting the ligaments to obtain freer shoulder motion. Cadenat[1] believes that it is the scapula which holds up the clavicle and not the reverse. When one attempts to pick up an object which lies in front of one, or to deliver a blow, two movements result, the first in the shoulder-joint and the second in the scapula and clavicle. When the arm reaches an angle of 45 degrees with the vertical axis in this movement, the acromion moves forward, because it is drawn by the posterior fibers of the deltoid muscle. This same movement carries the clavicle up and backward, stretching the posterior fibers of the acromioclavicular ligament and the trapezius.

Normal separation in the acromioclavicular joint is equivalent to at least 1 cm. Dislocations of the joint are complete and incomplete. The term "incomplete" signifies that although the capsular ligament and possibly the acromioclavicular ligaments are torn, the coracoclavicular ligament remains intact. In complete dislocation the normal displacement is exaggerated, and when the patient throws the arm forward as described, his scapula follows, drawn by the posterior deltoid fibers, and as the clavicle has lost its ligamentous attachment to the scapula, it seems to be unusually displaced upward and backward. Likewise, in abduction movements of the arm there is a slight forward sliding of the acromion. This knowledge is important in treatment of dislocation. If the treatment results in a fixation of the joint, there will follow limitation of reaching and abduction movements.

Dislocations of the acromial end are divided into supra-acromial or upward, subacromial, downward and behind the acromion, and subcoracoid, downward and forward beneath the coracoid process. The two latter are rare.

In Krönlein's 400 dislocations the 16 clavicular cases were divided into 11 at the acromial and 5 at the sternal end. The dislocation is

[1] Jour. de Chir., Paris, 1913, xi, 16.

complete or incomplete. The complete form is caused by falls from a height on to the shoulder region, or severe blows directed backward or upward and inward. A common cause in the young American is

Fig. 136.—Incomplete dislocation of the outer end of the clavicle.

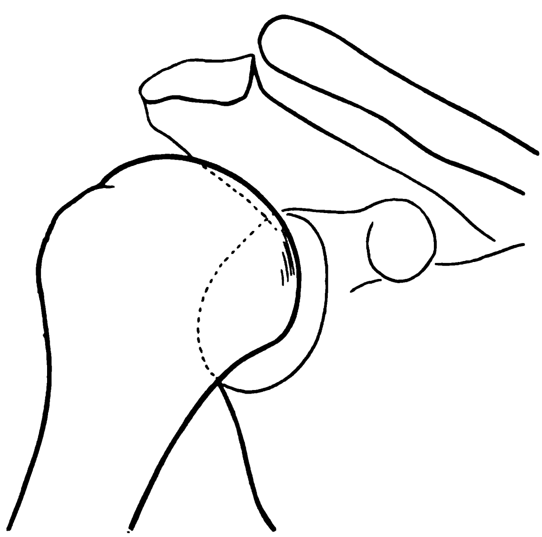


Fig. 137.—Complete dislocation of the outer end of the clavicle.

the trauma received in tackling an opponent in football. The full impact is received on the shoulder girdle, and incomplete dislocations are very frequent. Contraction of the trapezius and sternocleidomastoid muscle acts as an aid; in tackling injuries these two muscles are frequently in tonic contraction, and the sudden application of the opponent's weight causes a decrease in muscle length, a fact which pulls the clavicle up at its outer end. Falls from horses or over fences and obstructions are also causes. Nichols and Smith,[1] and Nichols and Richardson,[2] analyzed football injuries at Harvard University in the years 1905 to 1908, inclusive. They found that besides the tackling injuries another cause was the catching of a player's arm under a pile or a mass of men falling on an unprotected shoulder. In the year 1905 there were 11 cases in all, 2 of which were complete, the injured players finishing twenty-minute halves without complaining.

Cadenat[3] believes that the mechanism of fracture of the clavicle is usually caused by a transverse shock near the shoulder. For the obtaining of a dislocation there must be a force applied in front of or behind the deltoid region which bears down on the acromion. This force induces the scapula to rotate and tears the clavicle loose from the coracoid. When the force is not great there is an incomplete dislocation; when the force is excessive the acromion and coracoid are pushed farther down, the clavicle is unable to follow on account of the pressure of the first rib and the pull of the muscles above, the coracoclavicular ligaments are stretched so much that they yield, and complete dislocation is found.

Pathology.—Direct knowledge of the pathology is rare, depending on early open operation or death from other causes. One case of autopsy of a complete dislocation in Stimson's service at the Hudson Street Hospital was reported by Bolton.[4] Both the superior and inferior acromioclavicular ligaments and the coracoclavicular ligaments were torn across. In incomplete dislocations, the coracoclavicular ligament is not torn, but the separation of the joint capsule and the acromioclavicular ligaments permits a displacement as great as 2 cm. This is classed as a diastasis. Experimental work on the cadaver does not meet the conditions of actual injury inasmuch as the ligaments alone are subjected to tearing force and the restraining and assisting muscles are not acting.

A report of the detailed pathological anatomy in 2 cases has been made by Rocher.[5] One case was of a month's standing and was irreducible. An open operation revealed no hematoma. The end of the clavicle lay on top of the acromion covered by the aponeurosis and muscle fibers of the trapezius. When these were cut away the articular end of the bone came into view. The cartilage had been peeled off, and the clavicle could not be brought down into the acromioclavicular joint because of the interposition of fibrous tissue on the upper border

[1] Boston Med. and Surg. Jour., cliv, 3.
[2] Ibid. clx, 33.
[3] Jour. de Chir., Paris, 1913, xi, 16.
[4] Ann. of Surg., 1902, p. 586.
[5] Bull. et Mem. Soc. Anat. de Paris, 1910, lxxxv, 725.

of the articular surface. This tissue represented the meniscus and the joint capsule which had been completely pulled off the end of the clavicle. All was excised and reduction was then easily accomplished. The second case was a sixty-year-old man, who was injured by a carriage and sustained a dislocation of this point with other injuries. Within twenty-four hours a fatal ending resulted, and at the autopsy the end of the clavicle was found 6 cm. above the coracoid. It had slid under the aponeurosis of the trapezius. The deltoid insertion was torn out just below its upper border and the subclavian muscle was normal, except that it had been denuded of its covering. The superficial cervical fascia and the clavicopectoral fascia were torn, and the capsular ligament was completely torn off the end of the clavicle, leaving it bare. All the capsular ligament and the meniscus were attached to the articular surface of the acromion. Osseocartilaginous fragments which had been torn off with the capsule were adherent to the edges of the torn capsule. The conoid and trapezoid ligaments were torn off at the corocoid insertion, but there remained a few intact fibers stretched up between the two insertions. There was little blood extravasation present, and the sternoclavicular joint was intact.

After these dislocations and rupture of the conoid and trapezoid ligaments a process of calcification may infiltrate them and aid in stiffening the shoulder region. Grune[1] reported a case in a male forty-one years old who had suffered an incomplete luxation of the acromial end of the clavicle. He had pain in the shoulder, especially when the arm was raised above a right angle. There was also slowness of movements. A roentgenogram taken after several months showed distinct development of bone on the under side of the clavicle in both of the ligaments. Grune had a second case with similar findings nine months after a blow on the shoulder. This ossification undoubtedly comes from a tearing out of the periosteum and the irritation from too early movement and use of the joint.

Complete dislocation may become open, or the loosened end of the clavicle with the stripped up periosteum may ascend into the neck and produce great deformity. Injuries of vessels and nerves by the dislocated bone are almost unknown.

Other fractures or dislocations in the same shoulder may accompany the dislocation. Sprain fractures with tearing out of bone shells are frequently seen in the roentgenogram.

Symptoms and Diagnosis.—When the patient sits with the arm hanging, the acromial end of the clavicle rises higher than the one of the uninjured shoulder. Incomplete dislocations with slight separation do not show much deformity, and in recent cases this can be overcome by pressure down on the clavicle or upward on the arm. Crepitus and much swelling are absent. The trapezius and sternocleidomastoid muscles are in contraction and help hold the bone up out of place.

[1] Arch. f. klin. Chir., Berlin, 1911, xciv, 476.

Complete dislocations are characterized by a greater displacement and possibly overriding of the acromion by the clavicle. Pain in the joint and loss of function in the arm are variable, depending on the character of the causative force and the amount of displacement. Athletes and laboring men may not notice the disability at first. In a few hours pain and tenderness increase until the arm is held at rest.

Diagnosis is made on the apparent deformity and the finding by palpation of looseness in the joint and of the acromion's lying on a lower level than the outer end of the clavicle. The deformity is easily overcome by the operator's lifting up on the elbow and pressing down on the clavicle, and it returns when the arm is dropped. Fracture of the outer end is differentiated by greater pain, sometimes by crepitus being demonstrated, and by a normal relation between the acromion and extreme end of the clavicle. Measurement of both clavicles, for the determination of their length and the position of the deformity, will also help.

Large bone spurs and rickety deformities of the clavicle must also be differentiated. They are usually painless, their deformity is not influenced by arm movements, and they are bilateral. Contusion of the acromion area, bursitis, and sprains must not be overlooked. They lack definite signs of dislocation and usually subside with a few days' rest. The Roentgen picture is necessary in many cases.

Treatment and Prognosis.—Reduction, especially in incomplete cases, is often very easy. A hand in the axilla raises the shoulder mass upward and the other hand presses down on the clavicle. A soft crepitus of the reduction of displacement is generally felt; if it is absent, there may be interposing shreds of capsular ligament, or the outer bone end may have perforated through the fibers of the trapezius. If this is so, complete reduction can be accomplished only by open operation. In severe cases of complete dislocation and great displacement the shoulder must usually be brought backward and then raised to meet the pressed-down clavicle. Reductions of this class are a great disappointment; they may seem satisfactory, but recur before a retention dressing can be applied, or after a few days in the dressing are found to be as bad as at the time of injury. Several times I have seen carefully applied Desault or Velpeau bandages removed after two weeks' immobilization only to disclose the same old deformity present.

For incomplete dislocations these two dressings mentioned may be used, or Stimson's dressing of surgeon's adhesive applied over the shoulder and around the elbow supplemented by a swathe which holds the arm to the side. Nichols and Smith[1] used a modification of this dressing (see Fig. 138), and obtained satisfactory results in every case. Sayre's dressing for fractured clavicle is also used, with an extra strap over the displaced acromial end of the clavicle.

Nichols's modified dressing is applied after the shoulder is corrected.

[1] Loc. cit.

The first band of two-inch adhesive plaster (A) starts near the wrist, is carried over the padded elbow and back across the upper arm. The

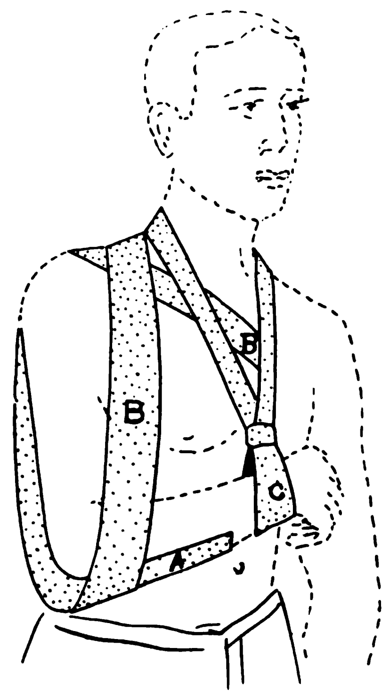


Fig. 138.—Nichols and Smith's dressing for discolation of the outer end of the clavicle.

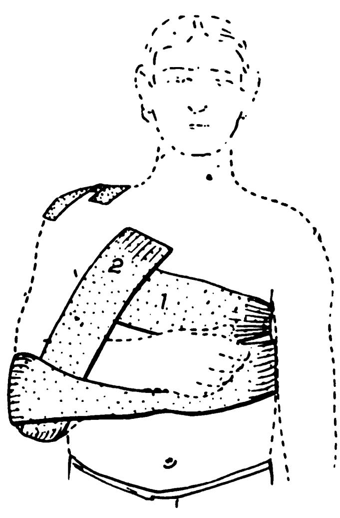


Fig. 139.—Bellamy's adhesive dressing for dislocation of the outer end of the clavicle.

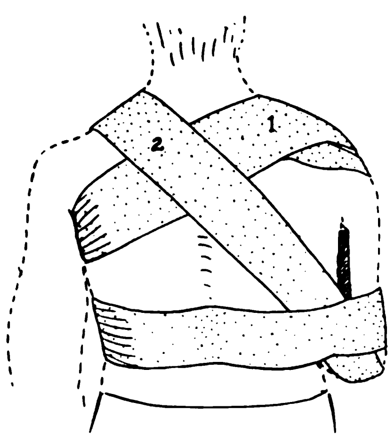


Fig. 140.—Back view of Bellamy's dressing.

shoulder is held back while the plaster is carried up to the base of the neck behind and forward over the shoulder to the chest. The second piece (*B*) starts on the front of the chest, goes up over the shoulder one inch inside the outer end of the clavicle, down back of the arm around the elbow and up in front to cross the first turn of the strap about the middle of the clavicle. It then passes over the shoulder and across the back. An axillary pad is used to prevent inward displacement of the shoulder (Figs. 139 and 140).

Operative treatment by wiring was first suggested and done in 1861 by Cooper, of San Francisco. It is often difficult to persuade patients of the necessity for operation for their condition when they have little pain and a fair function in the arm. Operation, however, is certainly indicated when there is complete dislocation and laceration of the coracoclavicular ligaments. Workingmen who need strong shoulders for work should be treated by operation even if the displacement is slight. It shortens the convalescence and gives a stronger joint.

The operation done by Cooper consisted of wiring the clavicle to the acromion. Kreck, in 1894, wired 2 cases.[1] Later, suture of the ligaments was proposed, and Elmgreen[2] modified the ligament operation by detaching the trapezius from the clavicle and fixing it to the first rib. Nailing was also done through the acromion into the clavicle,[3] and the most modern operative treatment consists in repair of ligaments supplemented by transplantation of fascial flaps when necessary. Many authorities agree that suitable permanent reduction is not possible, and that even the incomplete dislocations should be operated on. Others, in view of our present knowledge of the sternoclavicular articulation and the shoulder movements, believe that operation which fixes, like nailing, or which causes an ankylosis of the joint, causes a greatly restricted function. Cadenat[4] is one of these. He quotes Kappler and Pierre Marie, who saw 5 cases, in all of which the clavicle was completely removed or absent, with no loss of function. One group of 4 cases was in one family who all had congenital absence of the clavicle with no trouble in use of the arm. Opois[5] reported 6 cases of total extirpation of the clavicle for traumatisms with little functional disturbance.

Operations of today are of all these different types. They may be divided into (1) direct suture, (2) syndesmopexy, (3) ligamentoplasty.

1. *Direct Suture.*—Wires are inserted through drilled holes after exposure of the joint through a semilunar flap with the base toward the neck. Silk ligatures and kangaroo tendon are also used. Nails and screws can be inserted.

Lee[6] recorded an acromioclavicular dislocation in a nineteen-year-old boy received in football tackling. Reduction failed, and there was considerable loss of function in the shoulder. A vertical incision

[1] Münch. med. Wchnschr., 1897, No. 50.
[2] Zentralbl. f. Chir., 1899.
[3] Narath in Heidelberger Klinik, 1909.
[4] Loc. cit.
[5] These de Doctorat, Paris, 1907–08.
[6] Ann. of Surg., 1914, lx, 506.

was made over the outer aspect of the joint, and the articular disk of cartilage was found to prevent replacement. It was removed, and the ends of the clavicle and scapula were freshened. The fibers of the trapezius at the outer end of the clavicle were divided, and easy reduction followed. Fixation was furnished by three kangaroo sutures through the coraco-acromial ligament and clavicle and also through the coracoid process and around the clavicle. The arm was immobilized in plaster in a position of abduction for two weeks. The patient was then let out of bed and after five weeks the plaster was removed.

2. *Syndesmopexy.*—The reconstruction of the acromioclavicular and coracoclavicular ligaments can be done by sewing their torn edges together with heavy catgut, kangaroo tendon, or silk. Mattress stitches are the best.

3. *Ligamentoplasty.*—Ligamentoplasty is of use when the ligaments are torn and shredded beyond repair. A flap of fascia lata is transplanted, or the posterior fascia along the coraco-acromial wall is taken and sutured down over the end of the clavicle and the acromion by attachment to the remnants of the ligaments.

Ligament repair should always be done when wiring or other direct fixation is performed. Every operation should be followed by four or five weeks' immobilization in a Velpeau or Desault dressing until the joint is strong enough to start function. Results of non-operated cases may be satisfactory if the deformity is overlooked and the patient need do no manual labor. In laborers there is always a restriction of function when a suitable repair has not been made. The patient loses power to lift the arm high and has weakness in abduction and reaching. If the dislocation is incomplete and the joint has a play of a centimeter there is little disability. Complete dislocation unreduced gradually increases with loss of strength and pain in the shoulder. The loss of power eventually is so much that the arm cannot rise above 90 degrees. Operative results and prognosis are very good. The disability is short and union is prompt. Recurrence must be guarded against. Final functional results in three months are satisfactory.

Subacromial Dislocation.—Subacromial dislocation downward and under the acromion are rare, not more than fifteen being found in the literature.[1] The causes are generally direct violence by falls or blows on the outer end of the clavicle. Allen's case was caused by muscular action when a girl raised an axe above her head while chopping wood. The head of the humerus probably aids in pushing the end of the clavicle back under the acromion. There is depression of the top of the shoulder, change in the direction of the long axis of the clavicle, and pain and tenderness with ecchymoses. Function in the arm is greatly interfered with, and the brachial plexus may be pressed upon with numbness and tingling in the arm and fingers. The scapula is rotated and raised so that its inferior angle is unusually prominent

[1] Allen, New York Med. Record. xix, 206; and Eaton, ibid., xx, 734.

and its motions are restricted. The clavicle seems to point downward, its sternal end is painful to deep pressure, the sternocleidomastoid and trapezius muscles are held taut, and the head inclines toward the injured shoulder. If the swelling is not great the empty articulating facet of the acromion may be palpated.

Treatment.—Treatment is that of reduction and fixation. The shoulder is drawn outward and backward by a firm grasp and the chest is drawn forward by the two flat hands of an assistant. Theoretically, extreme abduction with elevation of the arm might aid. The clavicle can also be grasped and raised during these manipulations. In the recorded cases replacement has been easy. Open operation would be suitable for those cases which were irreducible or of long standing, with loss of function and pressure symptoms. The prognosis is fair. Function is good after reduction, and even without reduction the use of the arm is fair.

Subcoracoid Dislocation.—This condition is practically unknown, and the cases reported, 5 by Godemer and 1 by Pinjon, later reviewed by Malgaigne, are doubtful. The coracoid and acromion processes are supposed to be prominent beneath the skin of the shoulder. There is a depression of the outer end of the clavicle which may be felt in the axilla. Reduction would be made by drawing the shoulder backward and outward and pulling up on the clavicle.

Double Dislocation of the Clavicle.—There has been some confusion in the literature between double and total dislocations of the clavicle. Double dislocation can occur in symmetrical joints only. Total dislocation means simultaneous dislocation of both ends of the clavicle.

Von Kamptz[1] reported a double presternal dislocation of the clavicle. A double dislocation of the acromial ends was reported by LeBec. The only case of double retrosternal dislocation was seen by Geissler in a fifty-year-old man who fell about fifteen feet. Von Kamptz's case could not be reduced by manipulation, and open operation was resorted to. An instance of bilateral congenital sternoclavicular dislocation was reported by Gourdon.[2] In his article he states that Ferguson saw a similar case caused by accident during birth, and that Shaw has reported one of an anterior congenital dislocation of one side. Kappler noted a luxation of the internal extremities of both bones in an individual in whom there was congenital absence of the external extremities of the clavicle. Gourdon's patient presented a globular enlargement of the internal extremities which could be easily palpated as the ends of the clavicle. The condition was painless, and when the shoulders were thrown forward the sternal ends disappeared into their joints. The absence of the articular cartilage disk is believed to play an important role in establishing the continuity of this articulation. In congenital dislocations it is found that this cartilage is unstable. Gegenbauer remarked on its variability of form and dimension and its inconstant presence. Before the Anatomical

[1] Med. Klin., Berlin, 1913, p. 991.
[2] Revue d'Orthoped., Paris, 1913, 3 S., iv, 305.

Society of Paris, Poirier showed 2 cases of complete congenital absence of this cartilage. Unsatisfactory results have followed most operations for this condition. Gross and Brodier sutured the sternum to the clavicle. Hodgen performed an arthrodesis, but Gourdon did not operate on his patient because there was such good use of the arm.

Total Dislocation of the Clavicle.—There have been no cases of this dislocation recorded since Cousins,[1] which was the twelfth. His case was a total dislocation upward and forward of the right clavicle, the left being fractured. These cases are briefly:

1. Richeraud and Gerdy.[2] This was reported by Porral, an interne. The patient was twenty-four years old and the bone was dislocated forward and upward. There were fractured ribs accompanying the clavicular injury.

2. Morel-Lavallee.[3] The patient was forty years of age. Both ends were dislocated forward and upward. The other clavicle was fractured.

3. North.[4] The patient was fourteen years old. Both ends were dislocated forward.

4. Hutchinson.[5] A man had been caught between an engine and a platform. There were other injuries.

5. Stanley Haynes.[6] The case was that of a thirteen-year-old girl.

6. Col.[7] The patient was a girl aged seventeen years; both ends were dislocated forward.

7. Lund.[8] The patient was a man aged thirty-two years. Both ends were dislocated forward.

8. Rombeau.[9] The case was one of dislocation of both ends forward.

9. Hulke.[10] This was reported by Hudson, his house surgeon. The sternal end was displaced forward and the acromial end backward and inward.

10. Newman[11] reported a case four years after seeing it. The patient, a man twenty-four years old, had also ribs and opposite clavicle fractured, and retention of urine. He was never able to do hard work again.

11. Lucas.[12] This case was very unusual, because it was a simultaneous dislocation of both ends in a thirty-two-year-old man who was caught between two cart wheels and crushed. There was a marked round prominence at the outer end of the right clavicle, which stood up an inch above the acromion. The skin was so stretched over it that there was danger of its bursting through. At the inner end the clavicle was displaced backward and downward and left a deep notch

[1] Jour. Am. Med. Assn., 1906, p. 19.
[2] Jour. Univer. et Hebdom. de Med. de Chir. Pratique, 1831, ii, 81.
[3] Gaz. des Hôpitaux, 1859, No. 33, p. 130.
[4] New York Med. Record, April 16, 1866.
[5] Lancet, 1871, ii, 711.
[6] British Med. Jour. 1872, i, 99.
[7] Gaz. des Hôpitaux, 1872, No. 112, p. 893.
[8] British Med. Jour., January 24, 1874, i, 106.
[9] Bull. Génér. de Therapeut., 1874, p. 538.
[10] Lancet, 1885, ii, 245.
[11] Lancet, 1885, ii, 524.
[12] Guy's Hosp. Reports, 1889, xlvi, 445.

in the sternal joint. The shoulder fell downward and backward, and there existed a deep hollow in the lower part of the neck and the upper part of the chest. The two upper ribs were also probably dislocated backward, but there was no hemoptysis or surgical emphysema.

Nine cases have been in males and three in females, the ages varying from thirteen to forty years. The causes have been external violence on the upper and back part of the shoulder, except in one instance; usually severe crushes often accompanied by other injuries. The shoulder may be caught between opposing forces and the clavicle squeezed out like the pit from a cherry. Haynes's patient, an overgrown girl of tuberculous tendency, dislocated the bone while washing her neck. The displacement is generally the acromial end upward and outward, riding on the acromion, the sternal end forward and upward.

Good reductions were made in half the cases. Cases 2, 5, 6, and 11 were not reduced at both ends. Lucas's case probably had a primary reduction, but the patient left the hospital in a plaster dressing, suffered another accident in two weeks in which he felt something slip in his shoulder, but did not return until after four weeks, at which time the original deformity had partly recurred. The acromioclavicular end is reduced by the operator's carrying the elbow upward, the shoulder back and outward. The sternal end, if displaced forward, is reduced in the same manipulation by direct pressure. Lucas first reduced the acromial end and then made use of the clavicular origin of the pectoralis major muscle to draw the sternal end upward and forward, the arm being rotated outward and then drawn backward. This caused a replacement, but the bone tended to slip back out of place again.

An axillary pad is applied, and the arm can be bandaged to the chest, or a plaster dressing can be put over all. Hutchinson's case was treated by rest on the back, as was also Cousin's, supplemented by sand-bag pressure over the dislocated joints.

CHAPTER XII.

FRACTURES OF THE SCAPULA.

Anatomy.—The scapula is an important link in the shoulder-girdle structures. Description of its peculiar shape and muscular attachments is not necessary. It is known to originate from at least seven centers of ossification, and the body plate is so thin that it is transparent, or in some cases, lacking entirely in bone. The greatest interest in the bone from a standpoint of fracture exists in the acromion and coracoid processes and the glenoid cavity. There is a separate center of ossification for the acromion, but part of it is formed by an extension of the spine. The upper third of the glenoid cavity arises from a separate ossification center, as does also the coracoid process. Not only do these epiphyses not unite until about the twenty-fifth year, but bone continuity may never be established, fibrous union persisting throughout adult life.

Examination of the shoulder demonstrates the outline and position of the scapula. The spine, the acromial and coracoid processes, and the vertebral and axillary borders of the bone can be palpated. It is impossible to obtain satisfactory palpation of the glenoid cavity and its edges.

Fractures of the scapula are rare and are always caused by great violence. The bone is protected by heavy muscular layers on both surfaces, and the chest dome on which it rests is elastic enough to take up jarring force. The immobility of the bone in connection with shoulder movements is also a protection. The overhanging acromion and coracoid suffer in trauma more often than any other part of the bone; fractures of the neck and body are rare.

In my collection of 11,302 fractures at the Cook County Hospital I found that the scapula was fractured 81 times, about 0.7 per cent. of all fractures. Of these 81 fractures, 19 were specified as acromial; most of the others were of the spine, body, or glenoid. Mencke[1] collected all the acromion fractures for eight years, 1905 to 1912, at the German Hospital, Philadelphia. He found 89 cases. The fractures of the scapula are divided into those of the body, spine, acromion, coracoid, glenoid cavity, neck, and angles.

1. **Fractures of the Body of the Scapula.**—These are infrequent, the line of fracture usually passing horizontally from the vertebral to the axillary border in the infraspinous fossa. The fracture may be multiple, comminuted, or of any irregular formation. Displacement is usually not great, because the fragments are held in place by muscles,

[1] Ann. of Surg., lix, 233.

and because of the great violence which breaks the bone, fragments may be separated and caused to override and may persist in their displacement in spite of manipulation. In a transverse or oblique fracture of the body when displacement is present it is greater on the axillary border. This overriding is in the anteroposterior direction, and the lower fragment may also be pushed laterally by the causative force and held upward by the serratus magnus muscle. Muscular action also may cause fracture of the body of the scapula, just as it causes fracture of the inferior angle by contraction of the teres major.

Symptoms and Diagnosis.—There is pain in the scapular region, intensified on movement of the arm and shoulder. If there is separation and overriding of fragments, deformity in the scapula or its

FIG. 141.—Fracture of the body of the scapula originating on the axillary border.

borders is apparent, there are local tenderness, swelling, and ecchymoses with abnormal mobility. The inferior angle of the bone can be grasped by one hand, while the other hand steadies the spine or the shoulder, and the fragments can be moved. Crepitus is also commonly present. If the patient is very fat or muscular, the abnormal motility and crepitus may be demonstrated by the attendant's placing the flat hand firmly on the inferior angle of the bone and then adducting and elevating the arm. This movement drags the upper fragment with the shoulder girdle and demonstrates its freedom of motion from the lower fragment. In very thin patients the line of separation may be palpated, but the opposite scapula must also be felt if errors caused by normal ridges on the bone are to be avoided. The pain on active attempts to use the arm is a constant symptom and may reduce the arm function to nothing. Examination will

reveal a normal humerus and shoulder girdle and the local tenderness in the scapula. If the cause has been a severe violence like a run-over accident, the fracture of the scapula may be complicated by other injuries, usually involving the ribs or spine. Open fractures are rare, and infection is particularly to be feared in this region. The accompanying injuries and shock may make the fracture secondary. The usual course is uneventful, the fracture heals with little deformity, and should overlapping fragments unite without reduction, function is generally satisfactory. I have seen one case of fracture of the scapula with an excess callus on the costal surface which prohibited freedom of motion and caused pain by pressure.

Treatment.—If there is no separation of fragments and the fracture is comminuted, the arm and shoulders on the injured side must be immobilized three or four weeks in a natural position by the side. When there is overriding of fragments in oblique or transverse fractures, or the line of fracture runs through the spine, the misplaced portions of the bone may be brought into normal relation by manipulation of both the arm and lower fragment simultaneously. When a reduction is accomplished the arm must be immobilized in the position which obtains reduction. This is usually abduction, and elevation and an axillary triangle, or the plaster dressing described in the chapter on Fracture of the Clavicle, may be used. A small amount of displacement can be corrected by manipulation and pressure and can be held by a broad swathe of adhesive plaster placed about the chest from a point on the well side of the spinal column over the injured scapula and around on the anterior surface of the chest. The arm is prevented from moving and dragging the scapula by muscular action through being enclosed in a sling.

Operative treatment is applied to open fractures and to those cases of marked overriding which cannot be held in reduction by strapping. Open fractures are treated in accordance with the line of treatment advised under operative treatment, with particular attention to early thorough drainage and removal of fragments when suppuration starts. Closed fractures are sometimes wired after open reduction. I have seen two cases, both of which gave excellent results.

2. **Fractures of the Spine of the Scapula.**—Isolated fractures of the spine are uncommon (Fig. 142). The spine is frequently involved in comminuted and oblique fractures of the body, or in severe fractures of the acromion. Diagnosis is easily made on the signs of tenderness, swelling and ecchymoses, and the palpation of a loose piece of the scapula spine. If no other parts are involved, the spine may be strapped in position by an adhesive or cotton swathe run diagonally across the back and over the shoulder. The arm on that side must be immobilized by a simple sling or a Desault bandage and kept quiet for three or four weeks.

3. **Fractures of the Acromion.**—These are most common injuries of this bone. Mencke, as cited previously, found 89 in eight years in one hospital. Roentgen-ray examination of injured shoulders dis-

covers them in a surprisingly large percentage of cases. They may be divided into:

(1) Sprain fractures, caused by ligamentous or muscular tearing out of the bone surface.

(2) Epiphyseal separations.

(3) Distinct fracture of a large part of the process.

Mencke found in 40 cases examined by the Roentgen rays that 25 were sprain fractures, 8 were distinct fracture of the process, and one was an epiphyseal separation. Six cases were not traced. This disposition of fractures corresponds with the findings at the Cook County Hospital, where most of the acromial injuries are sprain fractures. These fractures are caused by direct violence of blows or falls on the

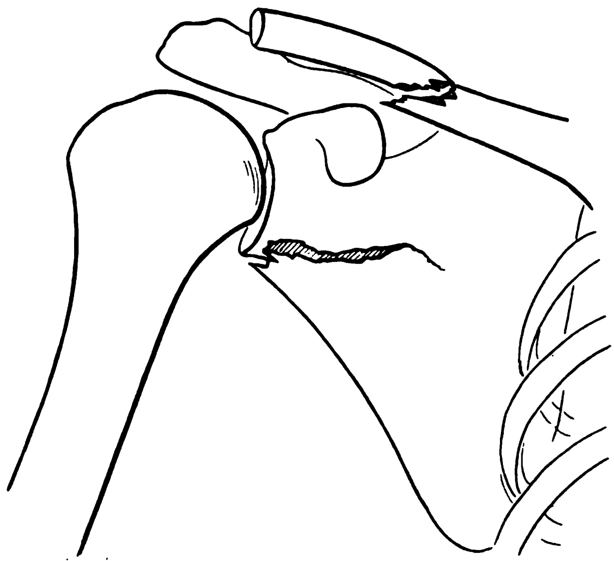


FIG. 142.—Transverse fracture of the scapula involving the neck, body and spine. There is an accompanying fracture of the clavicle.

shoulder; by indirect violence received from the head or greater tuberosity of the humerus, and from muscular and ligamentous pull in falls, blows, and dislocations about the shoulder.

(1) **Sprain Fractures.**—These represent the largest number of acromial injuries and are of interest on account of the long disability which follows neglected cases. The following classes can be differentiated according to location or cause:

(*a*) *At the Insertion of the Coraco-acromial Ligament Caused by Direct Violence Involving this Ligament.* The insertion is partly torn loose from the acromion; rarely a fair-sized splinter of bone is detached with it, to make in the roentgenogram a distinct separate shadow which lies anteriorly to the acromion. If no distinct bone fragment exists, the edge of the acromion is roughened, and after a few weeks

small calcification masses appear. Disability is caused by pain and stiffening of the deltoid muscle. Treatment is prolonged rest with baking or hot applications followed by active exercises when pain is *entirely absent*. The ultimate prognosis for shoulder movement is good.

(*b*) *At or About the Acromioclavicular Joint.* These sprain fractures are caused by direct violence or indirect violence like that causing dislocation of the acromial end of the clavicle. They are similar to the first class in appearance, the tenderness is located at the acromioclavicular joint, and they are differentiated merely by position. Disability arises from pain, and as the capsular and acromioclavicular ligaments are involved, pressure or tension on the clavicle may elicit extreme tenderness in the joint. Treatment is as for (*a*).

(*c*) *On the Upper Surface of the Acromion.* These are caused by direct violence like that received in injuries from falls, as a sliding on the shoulder-joint. They are very small roughenings of the bone, can be found only in a carefully viewed dried plate, and are not common. The disability is temporary.

(*d*) *At the Top or Outer Surface of the Acromion.* These are caused in two ways: The first is direct violence received on the extreme tip of the process, which splinters off the bone surface, and the second is indirect violence received by the acromion in the course of shoulder injuries. Fractures of the clavicle, dislocations of the acromial end of the clavicle, and dislocations of the shoulder cause all these sprain fractures indirectly. That is, shoulder injuries caused by abduction of the arm may injure the acromion by tearing out the ligaments, by springing the acromioclavicular joint, or by putting so much strain on the coraco-acromial joint that the great tuberosity of the humerus is applied forcibly to the acromion and breaks off a splinter by leverage.

The disability which threatens from secondary arthritis or periarthritis of the shoulder-joint is like that of all joint fractures, and although these lesions seem insignificant, the complications and loss of function demand early diagnosis and the institution of joint rest. Treatment is the rest and baking mentioned, and must be long continued.

Traumatic bursitis, which has a slower onset and is characterized by a slightly abducted position of the arm for relief of pressure on the disturbed bursa, must be differentiated.

(2) **Epiphyseal Separations.**—These are rare. They occur following any of the different mechanisms mentioned, more often the abduction strains of falls. There is a line of separation of varying width near the base of the acromion, tenderness, swelling and ecchymoses, and no crepitus. In studying the roentgenogram, cases of non-calcified union must be remembered. Treatment is rest and support of the arm in a sling or Desault bandage, the displacement usually being very small.

(3) **Fracture of the Process as a Whole.**—These fractures involve a distinct fragment at the outer end of the whole process well down into

the spine. The ordinary line of separation is oblique and is outside of the acromioclavicular joint. The causes are falls on the shoulder, direct violence of blows, or the indirect violence of abduction shoulder injuries, which force the humeral head directly upward or cause a leverage action of the tuberosity. There is localized pain, swelling, and tenderness. Crepitus is sometimes present. The palpating fingers may feel the loose fragment, and when the line of fracture is through or inside of the acromioclavicular joint there is a flattening of the shoulder on its superior aspect. The humeral head can be felt in the glenoid, the arm is not lengthened, and pushing up on the elbow does not decrease the deformity. This finding aids in differentiation from subglenoid dislocation and fracture of the glenoid neck.

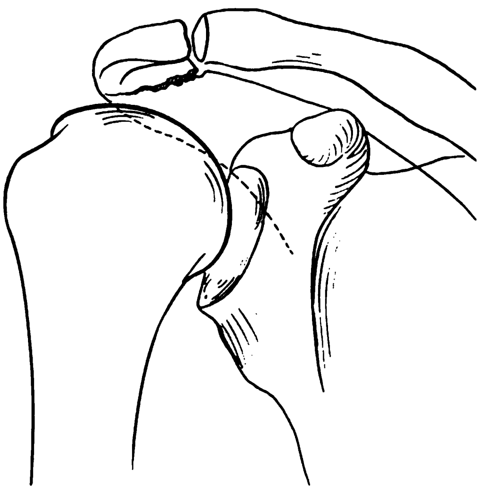


FIG. 143.—Fracture of the acromion process with little separation.

Treatment.—The treatment consists in the immobilizing of the whole upper extremity with the forearm left free in a sling. The Desault bandage, or one of those described under Treatment of Fracture of the Outer End of the Clavicle, is excellent. The reduction is made by the attendant pressing the arm upward against the acromion to relax the pull on the small fragment, aiding the reduction by external manipulation of loose fragments. The supporting bandage must be left on at least four weeks. When non-union results, or the fragment cannot be replaced, open operation is indicated for the holding of the bone by wire, or the removal of small fragments which threaten interference with shoulder-joint movement. Old cases with restricted abduction, which have been imperfectly reduced and in which bony union in malposition has resulted, are to be operated upon. It is better to remove entirely fragments which interfere with arm motion than to attempt to replace and fasten them with foreign material.

4. **Fractures of the Coracoid.**—These are frequent and are caused by direct and indirect violence and muscular action. Examples of direct violence are falls, football tackling and blows, and trauma from a dislocated head of the humerus. Indirect violence occurs in the abduction injuries at the shoulder and fractures of the clavicle. Muscular contraction of the biceps and coracobrachialis is a cause in severe exertion with the arm. Sprain fractures of the coracoid also occur following direct violence. Skillern[1] has reported a case in a football player. I have seen several. The mechanism is probably a tearing out of the coracoid insertion of the coracoclavicular ligament, and the extreme tip of the bone is not involved (Fig. 144).

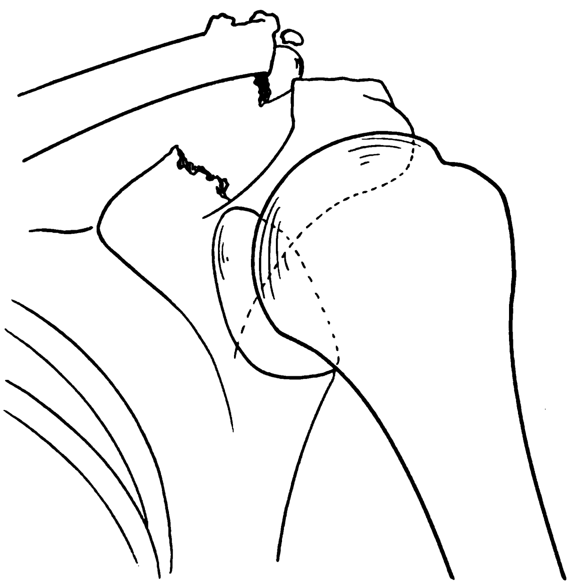


FIG. 144.—Fracture of the coracoid process with dislocation upward of the outer end of the clavicle. The acromioclavicular ligaments have partly held.

The site of ordinary fracture is near the base; displacement is slight because the coracoclavicular ligament holds the fragments. As in the acromion process, the ossification centre of the coracoid process may be split apart, or its failure to calcify may lead to diagnosis of epiphyseal separation or fracture from the roentgenogram. The plane of fracture may involve the base of the process and extend into the glenoid cavity. This fracture is caused by extreme direct violence. The symptoms are pain and tenderness on pressure, augmented by manipulation of the process. Swelling and ecchymoses appear, the discoloration spreading downward over the skin of the chest. I have at this time a patient with a fractured coracoid and other injuries, who has severe pain on slight pressure of the process and an ecchy-

[1] Amer. Jour. of Surg., lvii, 280.

mosis extending below the nipple on that side. Crepitus may be elicited in some instances, but the displacement is slight. Bony union is not the rule and function of the arm and shoulder is little influenced.

Treatment is replacement of the fragment and immobilization of the arm, as in fracture of the acromion. If the forearm is flexed, the muscles leading from this process are relaxed and pain is lessened, while bony union is favored.

5 and 6. **Fractures of the Neck and Glenoid Cavity.**—Fracture of the neck of the scapula is rare, the line of fracture passing from the suprascapular notch to the axillary border of the bone below the glenoid rim. These two types of fracture, neck and glenoid cavity, are grouped together because one sees them together. The line of fracture may start in the glenoid and pass obliquely to the axillary border of the bone, or the base of the glenoid may be comminuted. The lesser fractures of this region involve the lip of the glenoid, and though many of them are found in dislocations of the humerus, some are unrecognized after trauma and lead to stiffened shoulder-joints.

Gross fracture through the neck may cause separation of the coracoid process with the broken-off fragment. The acromion remains intact and by its ligamentous attachments limits the amount of displacement downward of the glenoid and neck.

The causes are direct violence or abduction shoulder injuries resulting from falls. The symptoms of scapular neck fracture are a flattening of the shoulder area below the acromion, which stands out prominently, and a lengthening of the arm. There is usually pain and swelling with crepitus when the humerus is rotated by a grasping of the elbow, and the condition is most often mistaken for dislocation of the shoulder. It is differentiated by the surgeon lifting up on the elbow to reduce the deformity and by not finding the head of the humerus in the axilla. Duga's test is negative. When the elbow support is removed, the arm drops again, and the deformity returns. This is a characteristic finding. In a case which I saw recently the following additional signs were noted:

Gentle rotation of the arm demonstrates that the head of the humerus rotates with the shaft, and there is little pain. If one hand is used to steady the scapula by pressure over the spine and shoulder, the other hand can raise the arm independently without causing the shoulder to rise. Some individuals normally possess lax joints, and there may be a small amount of normal motion of the humerus upward. This normal condition must be excluded. A roentgenogram taken through the shoulder at an angle of 45 degrees from the vertical axis of the arm will demonstrate the glenoid edge and part of the cavity.

Fracture of the glenoid lip and edge is not uncommon. In the last year I have seen four, one in connection with an old partial dislocation in which the humerus lay slightly forward of the glenoid. It could not be reduced by manipulation, and open operation disclosed the anterior and inferior edges of the glenoid cavity broken off and displaced downward. There was no means of holding the head

of the humerus in the shoulder-joint in a normal position, on this account and also because of periarthritic tissue thickening. The edge of the glenoid was chiseled off, part of the humeral head on the inner side was also chiseled off, and a muscular flap interposed. The result was fair functionally. Later I operated on a second case in which the pathology was that of a bony ankylosis caused by fracture of the glenoid rim. There was no history of dislocation. Beasly[1] reported a case of a fragment broken off the lower edge of the glenoid which tipped enough after union to force the head of the humerus up against the acromion. He does not state what position the arm was in but does mention that abduction was painful and restricted. The adhesions were broken up and the arm placed in a normal position. Good function resulted.

Treatment.—Treatment of recent glenoid fractures is immobilization of the arm in partial abduction until all soreness and pain have ceased in the joint. This will take five or six weeks, and if the primary rest of the joint has been thorough, fuller function will return rapidly. If joint motion is commenced before the process of callus formation and union have ended, irritat on will follow, and there will be restricted joint movement with pain. The old cases will improve under the modified arthroplasty previously mentioned. Forcible breaking up of adhesions and movement under anesthesia is a questionable procedure. In some instances satisfactory results may be obtained. Usually a firmer ankylosis follows.

7. **Fractures of the Angles of the Scapula.**—These fractures are rare, and really belong to the class of fractures of the body. They are produced usually by direct violence, although fracture of the inferior angle has been recorded arising from muscular action of the teres major muscle (Grimard).[2] The displacement is generally pronounced enough to be easily detected by palpation. There is pain and tenderness and crepitus, with the finding of a loose piece of bone. The attached muscles tend to maintain displacement, so that reduction is difficult and maintenance is almost impossible. Adhesive strapping and arm immobilization may suffice, because there is little disability following union with displacement of fragments. Open operation with wiring may be performed to obtain an anatomical reduction.

Fractures of the upper angle are very rare and are caused by direct violence. The line may be but a fissure, or the fragment may involve the spine. Treatment is the same as the spine fractures.

[1] Railway Surg. Jour., 1914, p. 260.
[2] Arch. Gen. de Méd., April, 1896.

CHAPTER XIII.

FRACTURES AND DISLOCATIONS OF THE RIBS AND COSTAL CARTILAGES.

Anatomy.—Along the vertebral border the heads of the ribs articulate with the bodies of the two adjacent vertebræ with a small joint surface and a strong ligamentous attachment. The neck and tubercle are also attached by ligaments and articulate with the transverse process of the vertebræ. The bodies are flat and curved. In front the rib extends into its costal cartilage directly without the interposition of a joint. The chondrosternal articulations, except that of the first rib, are true joints and are strengthened by the overlapping of the periosteum and articular ligaments. Between the costal cartilages from the fifth to the ninth there are also small synovial surfaces which are strengthened by ligamentous bands. The costal cartilages are composed of hyaline cartilage; the first seven prolong the ribs forward to the sternum, the eighth, ninth and tenth are articulated with the lower border of the cartilage above, and the eleventh and twelfth end in the lateral abdominal wall without anterior attachment. These ribs are called the "floating ribs." The cartilage is broadest at the rib end, tapering toward the sternum, and the intercostal distance gradually narrows from above downward. There is no fixed relation between rib length and cartilage length, as the cartilage gradually increases from the first rib to the seventh or eighth, the most prominent ribs, where it is between five and six inches long. The ribs anteriorly are easily palpated and can be identified except in fat persons. They are elastic, and the elasticity of the costal cartilage enhances this property. The clavicle protects the first two ribs; the last two are protected because of their floating character.

Causes of Fractures and Dislocations of the Ribs.—The relative immunity of the first two and last two ribs protects them, and most fractures occur in the middle ribs, the fourth to eighth. In childhood the bones and cartilages are so elastic that fracture rarely occurs. In 11,302 fractures admitted to the Cook County Hospital there were 883 fractures of the ribs, the number not quite equalling the number of fractures of the femur. The average age of the cases admitted during 1914 was forty-three years. By far the larger percentage is in males, about 77 per cent., on account of exposure and occupation.

The exciting causes are direct violence from falls or blows, and indirect violence by bending and compression, or, rarely, by muscular action. If the force is applied directly against a rib, it breaks by the usual method of compression. Infraction is rare. If the whole chest

is compressed, as it is in most cases, the indirect violence may cause the rib to give at a weak point, usually just in front of the angle. Anteroposterior compression tends to flatten out the normal curve of the rib, which naturally gives way at the point of greatest bending near the angle. Muscular action may cause fractures or dislocations in one lifting heavy objects, straining against a heavy burden, or violently sneezing, coughing, or laughing. The roentgenogram has proved in many cases that multiple fractures of the same rib or ribs are more common than clinical diagnosis would indicate.

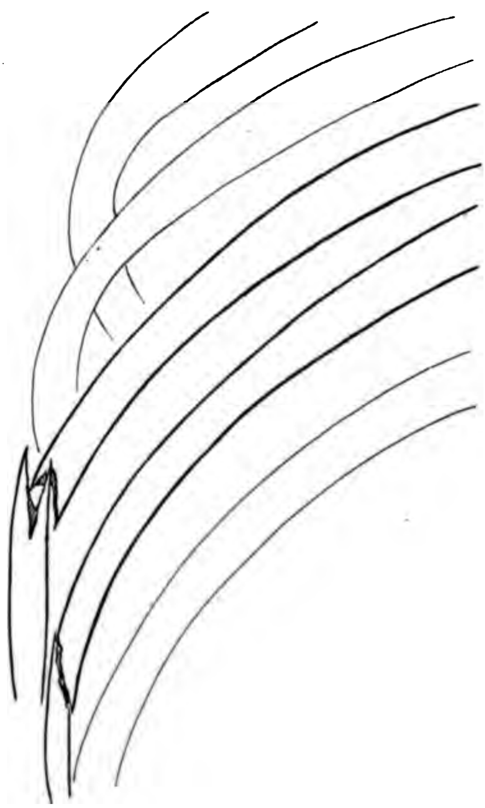


Fig. 145.—Complete fracture of a rib with some displacement. The neighboring rib is broken across but not displaced.

Pathology.—Fracture of a rib may be partial or complete (Fig. 145). The former is rare and consists of fissures or linear cracks across the bone with no separation. Complete fractures may be single or multiple, involving any number of ribs to the extent of all on one side of the body, or even on both sides, an occurrence which has been recorded in a few instances. The line of fracture is commonly transverse or oblique; it may be very irregular and jagged. The first two ribs are

seldom broken, but they may be involved in fractures of the clavicle or sternum, or are broken alone when violence causes depression of the clavicle (Fig. 146).

Single fractures usually involve the rib at points from the mid-axillary line forward, particularly because they are most often caused by direct violence, and the scapula and heavy back muscles protect the ribs posteriorly. If there are multiple fractures, or the cause is indirect violence from chest compression, the angle is a favorite site

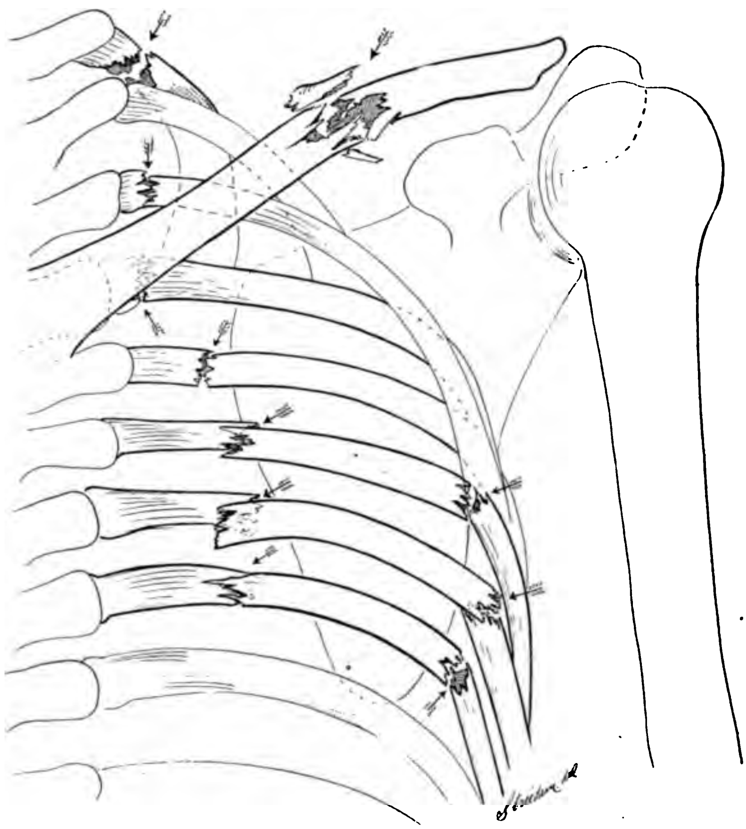


FIG. 146.—Multiple rib fractures involving even the first rib which is rarely injured. The clavicle is also broken. Looked at from in front.

of break. Direct violence may cause fracture of several ribs in front at the point of application, and as the force continues, pressing in on the bones, a second fracture occurs in the weak point behind. If several ribs are broken thus, the bones override, and a flat area of the chest is found. If the ribs are broken at one point, they may override slightly, the fragments assum'ng a slight angular deformity. Usually the periosteum is not ruptured on both sides, and this protection, coupled with that afforded by the muscles and neighboring bones,

prevents much displacement (Fig. 147). When a single rib is fractured, overriding is rare, but it does occur. I recall distinctly finding a healed rib fracture in the chest wall when removing the thoracic organs at an autopsy. Only one rib gave any evidence of fracture, and that was healed with overlapping of nearly a half-inch.

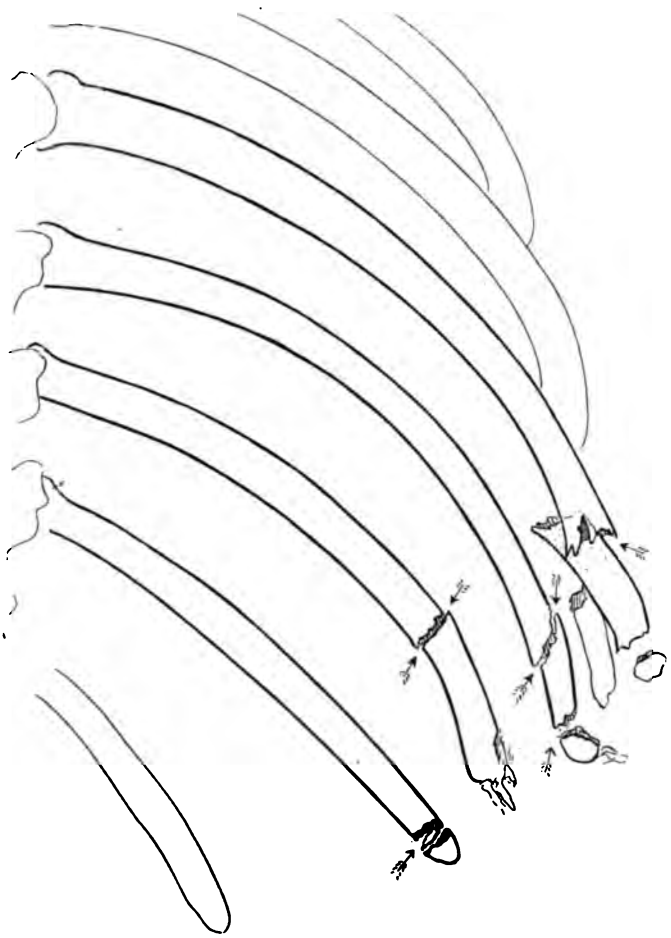


Fig. 147.—Multiple fractures of the ends of the lower ribs with loose fragments.

Open fractures of ribs are not common. It is doubtful if the bone fragments ever penetrate the skin after injury, but they frequently penetrate the parietal pleura or the lung. The fractures can therefore be opened in either direction, the opening through the skin surface being practically always caused by the object which produced the injury.

Complications.—Pleura and lung may be injured together or separately. Bone fragments are often driven through the parietal pleura, or the depressing of the bone causes the pleura to split open. Fre-

quently the lung is injured through being split by the trauma, even though the pleural cavity is normal. These complications lead to hemorrhage from the torn surfaces, or a collection of air in the pleural cavity from the outside atmosphere or the torn lung. When the two pleural surfaces are not adherent, hemorrhage may slowly fill the pleural cavity and cause death from lung collapse, anemia, or pressure on the thoracic viscera. Subcutaneous or surgical emphysema may also result from the pumping of air into the tissues from the lung direct, or from an external wound. If the lung is adherent to the parietal pleura by old adhesions, these complications are less likely to follow. The lung cannot collapse, pneumothorax has no opportunity to develop, and hemorrhage is circumscribed by the pressure of surrounding adherent tissues. Emphysema may be present with adherent pleura because the movements of the chest wall may force into the tissues air which has no means of exit and which is held by the valve-like closure of the wound edges during expiration. This may spread widely over the tissues of the body, involving the neck, face, and abdomen. With displacement after direct violence a fragment of bone may penetrate the lung and cause localized hemorrhage with hemoptysis, or localized pleuritis and lung consolidation.

Occasionally the intercostal artery is ruptured in fracture in its course just below the rib. Hemorrhage from this artery is brisk and may pour itself into the pleural cavity or directly into the lung, and result in pulmonary hemorrhage *via* the bronchi. Other complications are rare. The intercostal nerve may be pinched between fragments or caught in the callus. This causes pain from pressure neuritis, which lasts until the nerve has lost all function from continued compression. If one nerve alone is ruptured, there may be no area of anesthesia, on account of the overlapping of peripheral distribution of its neighbors. Empyema may follow fracture from infection of a hemorrhage into the pleura, or from direct infection from lacerated lung tissue. Osteomyelitis with necrosis of the rib may occur also from external or internal infectious sources. A lobar pneumonia may develop after rib injury.

Paralytic ileus has been noted as another rare sequel. Adams[1] reported 2 cases, 1 of which had no postmortem findings except rib fracture. The paralytic condition of the bowel probably results from irritation of the great splanchnic nerve which arises from the sixth to the tenth thoracic ganglia near the heads of the ribs. Any retention of gas or fecal matter in the bowel favors the condition, so that the condition of bowel stasis should receive early attention in treatment.

Pathology of Cartilage Injury and Dislocations.—The pathology can be divided into:

1. Dislocation of the ribs on the vertebræ.
2. Separation of the rib at its own costochondral junction.

[1] Annals of Surg., li, 102.

3. Separation of the costochondral cartilage from the sternum.
4. Fracture across the costochondral cartilage.
5. Separation of one cartilage from another at a level below the sternum.

1. Dislocation of the ribs on the vertebræ is found only in cases of extreme direct violence often associated with fracture of the transverse process of the vertebræ. If the transverse process is not broken, there must be laceration of all ligaments uniting the head and tubercle of the rib to the spine. The two lower ribs are the ones frequently dislocated, probably on account of lack of support anteriorly. The displacement is in any direction according to the force, and the kidney beneath may be bruised or lacerated by the trauma. The diagnosis is made by the finding of a break in the normal prominence of the ribs close to the vertebræ, the disappearance or undue prominence of the rib involved, and a lack of crepitus. The roentgenogram is essential to exact diagnosis.

2. Separation of the rib at its own costochondral junction is the commonest form of thoracic injury occurring up to thirty-five years of age. There is no true joint here, and the binding ligaments are weaker than those at the sternal junction. The periosteum is torn by direct or indirect violence, and the cartilage displaced from the small notch by which it fits into the rib. The rib may overlap the cartilage in front or behind with distinct displacement, and several junctions may be damaged simultaneously. The diagnosis is not difficult, because there is distinct displacement and no fracture crepitus nor much swelling to obscure the findings. Pain may be annoying, and union may never occur; when it does it is bony.

3. Separation of the costochondral cartilage from the sternum is more often a subluxation than a complete dislocation because of the complexity of the ligamentous attachments. It is commonly the result of indirect violence or muscular action in adolescents overstraining in physical competition or gymnasium work. The displacement may reduce itself, and the diagnosis is made on the constant point of tenderness, lameness affecting the chest or arm, and a thickening along the sternal margin.

4. Fracture across the costochondral cartilage is usually transverse and is often overlooked. Displacement varies; one part lies in front of the other or no separation at all may exist. The diagnosis does not depend on symptoms in any way different from those of the foregoing classes, but is merely an anatomical one. Union is by bone.

5. Separation of the cartilages from each other occurs in the group from the sixth to the tenth ribs which form the epigastric arch. This, a common injury, results from direct or indirect violence. Diagnosis is made on the persisting soreness to pressure or the movements of respiration. Coughing or sneezing are also painful. There is no crepitus, and the symptoms are located anteriorly. Deformity is rare. One rib may slip from the other on deep inspiration, with a click which is felt by the patient, and after healing a small mass may be palpable.

Symptoms.—Fracture of one or possibly two ribs may give few symptoms. Pain in the chest, soreness, stitch in the side when sneezing or laughing are the common findings. After compression or a blow on the chest soreness is likely to be diffuse, and although detailed examination of the course of each rib is made, the surgeon may not be able to name the bones involved. Crepitus may sometimes be elicited by pressing on the sternum or spine, or it may be felt by the patient on deep inspiration. When the chest wall is thick and the soreness diffuse, it is unnecessary to cause distress by search for crepitus. If it is not readily made out by pressure in front and behind on the suspected rib, it may be felt by palpation with the palm on the chest wall, or heard by the stethoscope on deep inspiration. If several ribs are broken, the patient invariably assumes an attitude with body bent and head inclined toward the affected side to reduce the amount of motion in the chest. He may also hold the side with the corresponding hand. Deformity of the chest contour and a looseness of fragments are found only in severe and multiple fractures. After a day or two the point of tenderness to palpation or the pain of chest movement becomes more localized, and the patient can often put his finger on the spot of greatest distress.

Pleuritic pain may appear secondarily. Hemoptysis may also be an early symptom, if any of the complicating causes are present. When this continues with pain, the surgeon must suspect that a fragment of bone has penetrated into the lung tissue. The symptoms of hemothorax, pneumothorax, and collapse of the lung are those of shock and air hunger and the chest findings on physical examination, which go with the respective conditions. Subcutaneous emphysema may start early and become alarming in its spread. The subcutaneous tissues become swollen and crackle on pressure. Respiration may be greatly embarrassed, and this complication may interfere with treatment and threaten life. Injury of the pericardial sack or the heart itself has been reported in rib fracture. In elderly people late complications may result which involve cardiac weakness and dilatation from long-continued pain and loss of sleep.

Course and Prognosis.—Fracture of a single rib caused by direct violence has a painful course for the first week, followed by gradual relief and ultimate recovery in three to four weeks. If the patient keeps relatively quiet and has proper treatment, he may experience little sharp pain, unless there is pleurisy or chest movement from a reflex cough. If the patient desires to remain in bed, the most comfortable position is a sitting one. Deep inspiration, sighing, laughing, and sneezing are to be avoided. After a week the pain decreases, and the patient can get about, but must avoid vigorous use or abduction and elevation of the arm on the affected side in dressing. Callus can nearly always be palpated and may lead to the complications mentioned. Rarely several proximate rib ends may solidify together and form a bony mass in the chest wall, or a gap may develop through which a hernia of the pleura and lung appear. I have seen one such

case, complicated by rupture of the diaphragm. The rib fractures were open, the diaphragm was sutured through their opening, and when the chest wall healed there was a large hernia of the lung outward beneath the skin scar. The complications alter the usual course because the fracture alone is secondary. Hemorrhage from an intercostal artery, subcutaneous emphysema, pneumothorax, and penetration of the lung with hemoptysis may produce alarming symptoms and cause death. Generally emphysema disappears in a few days. Traumatic asphyxia following severe compression of the chest accompanied by rib fracture is also a serious complication in the course. There is a marked cyanotic color of the skin of the face and chest and a capillary hemorrhage in the skin and beneath the conjunctivæ. The condition is caused by the traumatic intense passive congestion of the head and neck tissues with interstitial hemorrhages, which probably also involve the mucous surfaces of the respiratory tract. The blue color with dyspnea lasts for several days.

In multiple fractures some permanent deformities of the chest contour persist. After dislocations and separations of cartilage and bone some deformity is the rule, but there is no pain, and function of the affected side is not much impaired. Arm movements may be impeded slightly. If non-union remains in cartilage fracture, the joint may slip out of place when the patient assumes certain positions, but it easily replaces itself and is painless.

Treatment.—Simple fracture of one or two ribs requires relief of pain most prominently. Treatment must also look toward the correction of displacements and the care of complications. To reduce the pain and to control chest movements which may result in pain or pleural irritation, the portion of the thorax involved in the fracture must be immobilized. If but one rib has been broken and it lies in the area of the prominent ribs which possess most movement, the lower two-thirds of the chest must be held quietly. Ordinary respiratory motion may cause no distress, but sighing or laughing or an inadvertent deep breath cause sharp pain, as do also unexpected movements of the arm and trunk. Cough is also an every-day accompaniment of rib injury, especially in elderly people with emphysematous chests and chronic bronchitis. For control of the pain strapping of the chest is indicated.

Adhesive plaster is applied in a wide swathe extending from a point on the well side of the chest across the midline of the back, around under the arm to a point on the anterior surface beyond the midline of the sternum. This is tightly drawn into position while the patient makes a complete expiratory movement and holds the chest with the ribs relaxed as much as possible. An excellent position is one in which the patient stands with feet apart and well braced, the arm on the affected side abducted and the hand held toward the head. The surgeon fastens the plaster in the back, the patient braces the feet, makes the deep expiration and the plaster is pulled as tightly around the injured side as it can be drawn and is made adherent on the front

surface under all the tension that can be applied. Relief from pain is immediate and lasting, because the unaffected side of the chest is left free for respiratory movements. The ribs on the affected side are relaxed into a normal position unless there is uncorrected overlapping and are held restricted so that inspiration fails to cause their movement and the pain which would follow the movement of the bone fragments with excursion of that side of the chest. The immobilization controls cough arising from reflex irritation from bone fragments or ruptured pleura, and if there is cough present from other causes, the strapping lessens its painful character by holding that side of the chest quiet. This treatment also fulfills requirements when there is hemoptysis caused by lung ulceration from bone fragments. It has always been my habit to use narrow strips of plaster one to one and a half inches wide applied successively in the manner of the swathe, each piece slightly overlapping its neighbor. If the seventh rib is broken, the first strip of plaster is applied in expiration well below the site of fracture with use of as much pressure as can be applied to hold the chest quiet. The plaster is put on without any wrinkles to make pockets on the sticky surface in which sweat may gather and cause skin maceration or infection. Each strip is added, building from below upward as high as necessary to overcome motion, and the finished dressing becomes one wide swathe when all is adherent. It has distinct advantages over a broad swathe, because there is pressure in each width to hold the part immediately underlying, and the whole effect gives greater immobilization of the chest wall. The broad swathe has more or less of a uniform tension about the whole side of the chest and does not allow for the fact that the lower ribs can be compressed more because of greater elasticity. The strips must not be applied below the costal arch to pass over the epigastric area or to be fastened to it. This region must move in the movements of respiration, and if strapping is adherent to it, motion is transmitted to the chest. Fat persons are difficult to strap satisfactorily, because the subcutaneous adipose tissue stretches and gives enough to lessen the tension of the plaster. This can be guarded against by carrying the plaster a little farther on to the well side both in the front and rear. Stout women or those whose breasts interfere with this treatment can be relieved by the use of two or three bands below the breast which run up in front between and leave the opposite breast free. The lower portion of the mammary gland can be held up and included in the strapping, but the edge generally cuts into the overhanging delicate skin and causes irritation within a few hours. The nipple should never be strapped over. The modern corset, which fits snugly about the lower ribs and epigastrium and leaves the upper chest freedom of respiratory motion, is a useful adjunct in fracture of ribs in women. The corset may be drawn up tighter than usual and an aseptic pad of gauze or cotton can be laid over the injured area and then be held by the corset closing over it, much as a truss pad holds in a hernial protrusion.

When the fracture site is on the fourth rib or higher, strapping cannot give much relief. The axilla prevents the application of a continuous compressing plaster dressing on the whole side. Chest movement may be restricted by bandaging of the arm to the side or by use of leather or light plaster-of-Paris forms which are strapped on over the opposite shoulder. Practically these are little used. The patient is kept quiet in bed or in a reclining chair, and a sedative cough mixture is given to control respiratory excursion.

Strapping with adhesive plaster is contra-indicated when the skin is excoriated or abraded. I have seen removed from damaged skin plaster swathes which left behind a suppurating, eroded skin surface of large extent requiring weeks to heal over. The same condition may follow plaster left on too long or applied over dirty skin. Skin which has been cleaned with alcohol and carefully dried before application of the plaster will tolerate the dressing eight to twelve days with no great trouble. It should then be removed and reapplied if necessary. When pneumonia develops or respiration is embarrassed from pneumothorax or other conditions, adhesive strapping must be removed, and the pain caused by the fracture must be controlled by anodynes or local applications of cold.

Reduction of displacement in fracture of the ribs is not of great importance, unless the displacement increases or is the cause of pain, or a bone fragment has penetrated the lung and caused damage or a surgical emphysema. Roentgen-ray study of injured chests proves that the ribs are often broken in two sites, when only one is clinically diagnosed. The portion of bone between the two fractures cannot readily be reduced and held in normal position on account of muscle stress. If several ribs are broken with an angular deformity, it is wise to attempt reduction of this before strapping. The shoulders are grasped and pulled backward by an assistant while the surgeon presses laterally on the displaced ribs with his flat hand, the patient being instructed to inspire deeply to force out the depressed fragments. This procedure may produce a successful reduction—or, more likely, the deformity recurs before the chest can be fixed firmly in the reduced position. Deformity in one or two ribs may be reduced by local pressure aided by the manipulation described, and a firmly applied strip of adhesive plaster applied at once in the rib axis often holds the reduction.

The various dislocations are on the whole treated as fracture. Dislocations of the head of the rib on the vertebræ are not amenable to simple treatment, nor do they demand interference unless there is hemorrhage or nerve pressure. One can attempt reduction by having the patient cough or strain violently toward a position of flexion of the thoracic spine, the shoulders being elevated at the same time. The only direct reduction which can be made is by open operation, which is rarely called for, because non-reduction produces no other trouble than some lameness in the muscles of the back.

Separation of one cartilage from another at the level below the sternum, or fracture across the cartilage does not lead to much deformity and is treated by strapping. If the deformity is great, manipulation with chest expansion and shoulder retraction will permit reduction. If these fail, resort must be had to operative treatment. Separation and dislocation of the rib from its cartilage or the cartilage from the sternum is likely to give more displacement, if more than two ribs are involved. The same methods of chest expansion and manipulation should be used, and it is often better to leave a permanent deformity than it is to operate in that area. Displacement may be backward as well as forward and the rib ends in the epigastric region may sometimes be grasped in the fingers directly and reduction accomplished by traction and pressure. Results after healing without reduction are quite satisfactory, although the deformity is permanent and the chest is not strong enough for heavy work.

Operative treatment and treatment of complications are nearly always synonymous. One seldom sees fractured ribs operated on to correct deformity. Dislocations, especially in the costochondral region, are sometimes corrected by open operation. If there is an open wound at the time of injury, the displacement should be corrected. Displacement outward at the site of fracture of one or more ribs can often be replaced by pressure. In patients who have fat thoracic walls the displacement may not be recognizable, and in muscular subjects the displacement returns at once. A small incision in the rib axis, which exposes the periosteum of the bone, may permit leverage of the fractured ends into alignment. Persisting overlapping may be cured by cutting off of a portion of the forward fragment and establishing realignment. If the pleura is torn, pneumothorax follows, which may cause more trouble than the original injury. As a matter of fact, operation is seldom performed.

Hemorrhage from the intercostal vessels or the lung tissue is operable under some circumstances. It is difficult to diagnose the exact cause of the hemorrhage and in multiple fracture to determine the site. If there is an open wound and the intercostal hemorrhage is external, that vessel can be found by enlarging the wound. When the hemorrhage is internal into the pleural cavity or lung it may be concealed. There are two choices of treatment: one is to give morphia and keep as much blood in the extremities as possible by constrictions about the hips and shoulders, and the other is to cut down at a known site of fracture to find the bleeding vessel. Schütte[1] states that the mortality of hemorrhage into the thoracic cavity is 40 to 60 per cent. in untreated cases. In 12 cases of recorded operation 9 patients recovered.

The chest wall may be uncovered by a horseshoe incision with its base toward the sternum. The skin and superficial tissues are dissected back and the bleeding intercostal vessel is searched for

[1] Münch. med. Wchschr., June 30, 1908, p. 1386.

and tied. If the hemorrhage comes from the lacerated lung, the ribs and parietal pleura are divided and turned back in a large flap toward the sternum. The lung is seized and the lacerations are sutured with catgut, after which the chest wall is closed by layer suture without drainage.

Pneumothorax may demand aspiration of the air into a vacuum bottle. Late operations are indicated when the intercostal nerves are squeezed in callus or thoracic empyema or necrosis of a rib develops. These infections are treated by drainage or rib excision.

Spreading surgical emphysema is treated by pressure bandages or adhesive strapping. If it becomes an impediment to respiration, multiple incisions through the skin and fascia are indicated to allow the escape of air. Generally the condition slowly subsides, and the air is absorbed after many days. When the crushing of the chest is severe and the subcutaneous emphysema develops rapidly, multiple openings do little good and often add to the shock. I have seldom seen severe cases of this character recover, not so much on account of the emphysema, perhaps, as on account of the accompanying injuries and shock.

CHAPTER XIV.

FRACTURES AND DISLOCATIONS OF THE HYOID BONE AND STERNUM.

FRACTURES AND DISLOCATIONS OF THE HYOID BONE.

THESE fractures are very rare. Gurlt collected 27 cases and Stimson has seen 3 cases. Most are associated with fracture of the thyroid and cricoid cartilages in the neck. They are caused by throttling, suicidal attempt at hanging, or direct violence of blows in the hyoid region.

Anatomy.—This small bone lies between the tongue and larynx in close relation with each. By its muscular attachments to the tongue and thyroid cartilage, it acts as the principal support of the tongue. It is also associated with all the movements of the larynx. The degree of looseness of the lateral thyrohyoid ligaments which unite the major cornu of the hyoid to the superior cornu of the thyroid cartilage has a bearing on dislocation of the major cornu. This ligament may be partly ossified in old age, and injuries of it may simulate fracture. Likewise, traumatic inflammation of the joint where it unites with the hyoid may symptomatically resemble fracture and dislocation.

The site of fracture or dislocation is usually at the junction of the major cornu with the body of the bone, or, rarely, in direct violence, the body of the bone itself has been broken. The symptoms of fracture are acute pain and swelling in the region of the bone, accompanied by attacks of suffocation and dyspnea. There is pain in the throat when the patient attempts to talk or swallow. Swallowing may be impossible, and the tongue cannot be protruded. Crepitus, or a loose fragment, may be felt on manipulation. Complications exist because of rupture into the larynx or concomitant injuries of the trachea or thyroid cartilage. Isolated fracture or dislocation of the hyoid bone does not lead to subcutaneous emphysema, so that if this symptom is a prominent one, fracture of the thyroid and tracheal cartilages must be suspected.

Dislocations of the major cornu are nearly as frequent as fracture; the pathology of the two is intermingled and the symptoms are similar. In all there are 11 cases on record, the last being added by Hazelhurst.[1] The literature of this condition was first mentioned by Olivier D'Angers.[2] He stated that the dislocation was first described by Valsalva, and on account of the prominent symptoms of dysphagia it

[1] Johns Hopkins Hosp. Bull., 1912, xxiii, 344.

[2] Dict. de Méd., Paris, 1837, 7th ed., xvi, 105; and Bull. de Therap., Paris, 1836, x, 91-93.

was later called dysphagia valsalviana by Sauvage. The second and third cases were described by Mollinelli.[1] In 1 case a young student had been assaulted and throttled by pressure on the right side of the neck. Other cases have been recorded by Mugna,[2] Gibb, who saw 5 cases in all,[3] and Ripley.[4] Since that time Westmoreland,[5] Daly[6] and Wood[7] have added cases.

These instances of dislocation of the major cornu have been of varying degree inward or outward and downward. The causes are choking or throttling pressure on the outside of the neck or pressure from within the neck by attempts to swallow large bodies, such as large pieces of meat. By direct violence the major cornu is displaced inward; its articular facet is pulled away from the corresponding face of the body of the bone. Violence from within the throat in swallowing causes a lateral and downward movement of the larynx, so that one of its horns impinges against the corresponding superior horn of the thyroid cartilage and remains there. One of Gibb's cases was examined at autopsy. The man had felt a sticking sensation in his throat which examination proved to be the displaced left major cornu of the hyoid. Dissection showed there was a pouch filled with clear fluid about the thyrohyoid articulation. This contained a large rhomboid-shaped, sesamoid bone, which had developed in the outer wall of this pouch. There was much motion in this joint.

Of the 11 cases recorded, 2 gave evidence of local tuberculosis in the thyrohyoid articulation and larynx. None showed traumatic laryngeal changes. Three were in physicians. There was pain in swallowing in 6 cases and total inhibition of swallowing in 2 cases, 4 showed anxiety and 3 had a feeling as of a foreign body blocking the throat. Voice and respiration may remain unchanged, in marked contrasts to the dysphagia. Four cases were reported caused by sudden movements of the jaws and neck in yawning, coughing, or singing, and the same number were caused by direct trauma of choking from without or from within by the ingestion of large masses of food.

Reduction treatment has been successful in all the cases. This is done by gentle pressure or rubbing over the displaced part or by putting the anterior neck muscles on a stretch with the head held back. The jaw is then suddenly depressed, and the depressors of the hyoid bone pull it back into place. The same mechanism is accomplished by the attendant's making a firm grasp below the hyoid, having the patient swallow vigorously, and simultaneously giving a sharp, quick pressure on the displaced fragment, which produces reduction. If these methods fail, the surgeon's finger is inserted into the mouth at the side of the

[1] De Ossis Hyoidi luxationi, Bononiensi Sc. et art. Inst. Comment. Bononiæ, 1767, v, Part 2, p. 106.

[2] Annali Universali di Med., November and December, 1828.

[3] Lancet, London, 1859, xxxii, i, 512.

[4] Hamilton, Fractures and Dislocations, 7th ed., p. 646.

[5] Tr. Med. Assn., Georgia, 1889, xl, 189, and Atlanta Med. and Surg. Jour., 1889–90, vi, 189.

[6] Arch. Laryngol. New York, 1880, i, 162. [7] Lancet, London, 1890, lxviii, 68.

tongue anterior to the tonsil which corresponds to the injury, and makes pressure downward and forward. The fingers of the other hand make a slight pressure externally on the neck at the site of injury, and in some cases reported, the sliding back has occurred with a distinct click. If the larynx has been punctured in fracture of the body or the respiration is seriously embarrassed by the displaced fragment or swelling, tracheotomy may be called for at once.

There is immediate relief of symptoms after reduction. The condition is likely to recur. This was so in 6 of the 11 cases recorded. In Hazelhurst's case it had first occurred when the patient was seven years old. By the time he was twenty-three he was able to "set" the bone himself.

FRACTURES AND DISLOCATIONS OF THE STERNUM.

The sternum is composed of three parts, the manubrium, body or gladiolus, and the xiphoid process, the whole averaging six and a half inches in length. It is composed of cancellous bone like the bodies of the vertebræ, and has a thin cortex and a rich blood supply. The heaviest part of the bone is the manubrium, which rarely has osseous union with the body, a true diarthrodial joint often existing between them. The centres of ossification and the adult condition are illustrated in Figs. 148 and 149. At the upper end this bone articulates with the clavicle and along the side of the body with the upper seven costal cartilages. Irregularities in development are met with, one form of longitudinal fissure leading to confusion with fracture.

On account of the late union of the component parts, dislocation of the manubrium from the body is more frequent than true fracture, which is rarely seen before the third decade of life. If a bony union exists between the two upper parts, a true fracture is present when they are forcibly separated. Protection of the vital structures behind the sternum is furthered by the elasticity of the chest, contributed by the ribs on which the sternum rests. This elasticity, the cancellous structure of the bone, and its division into segments, make for the rarity of this injury. Satisfactory roentgenograms of the sternum cannot be obtained consistently, so that after injury it is impossible to tell whether bony or cartilaginous union or a true joint existed between separated fragments. Consequently fractures and dislocations furnishing similar clinical symptoms will be considered together.

Occurrence.—In eight years at the Cook County Hospital in the series of 11,302 fractures the sternum was injured twelve times. The large majority of fractures are in males; there have been recorded cases of fracture of the bone in women during labor.

Causes.—The causes of fractures of the sternum are direct and indirect violence and muscular action. Direct blows on the chest, as in car-bumper accidents, compression injuries, accompanying fracture of the spine from hyperflexion, run over accidents and falls, are the usual etiology. Severe muscular exertion from contraction of

the sternocleidomastoid and abdominal muscles in falls, or in women in labor, may separate the bone. Hamilton[1] mentions a case related by Malgaigne, of a mountebank who fractured his sternum when leaning backward to lift a weight. Violent coughing or sneezing may also dislocate the sternum, but the bone must be atrophic. Rib fracture may accompany the injury.

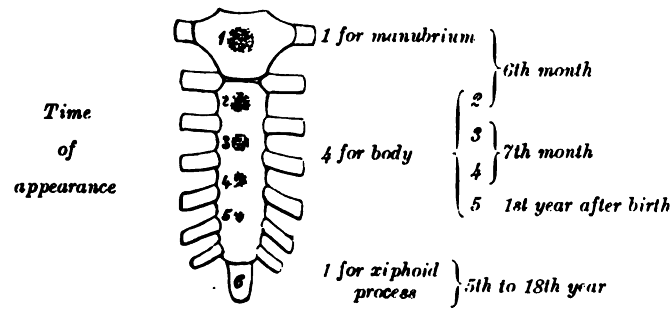


FIG. 148.—Ossification of the sternum.

Pathology.—The line of the fracture is often transverse near the junction of the manubrium and the body or a dislocation diastasis of the joint. This is about the level of the second costal cartilage. Fracture may also be an incomplete crack or the tearing out of a shell of bone, as is found in dislocations of the sternal end of the clavicle,

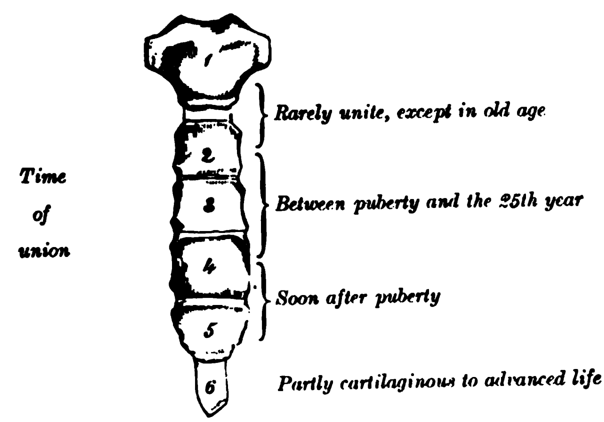


FIG. 149.—Order of union of the various ossification centres of the sternum.

or a costosternal junction. Multiple and comminuted fractures are caused by extreme violence, especially gun or cannon shots. Oblique and longitudinal fractures are very unusual and must not be confused with fissures of irregular development. Compound fractures other

[1] Fractures and Dislocations, sixth edition, p. 181.

than those of gunshots are almost unknown, unless incidental to other fatal injuries in crushing accidents.

The usual displacement in transverse fractures is of the lower fragment forward, with possible overriding (Fig. 150). Stimson states that there is but one true example of longitudinal fracture, in which one-half was depressed somewhat below the other half, reduction being made by abduction of the arm on the depressed side with pressure on the higher riding half of the bone. The periosteum is not always torn on both surfaces of the sternum. Usually there is complete rupture in front, while the posterior layer is stripped up but retains continuity. This fact is important, because it saves the mediastinum from extravasation of blood.

Other pathology deals with complications. There is one case recorded in which a fragment was driven through the skin by indirect

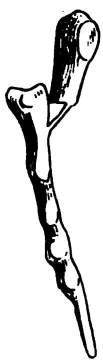


FIG. 150.—Usual displacement in transverse fractures of the sternum. (After Cotton.)

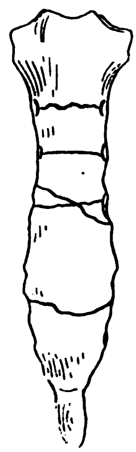


FIG. 151.—Types of sternal fractures found in the Warren Museum. (By Cotton.)

violence. Injuries of the sublying thoracic viscera are common in gunshots, not in simple fracture. Rupture of the pericardium or of the heart itself has been reported. The costal cartilages or ribs may be fractured. Spicules of sternum or ribs may puncture the lung and cause emphysema of the tissue, pulmonary hemorrhage with hemoptysis, and severe cough or pneumonia. The mediastinal spaces and pleura are sometimes penetrated, and collections of blood which become infected from open wound or bacteremia result in abscess.

Rupture of the posterior periosteal covering, or injury of the internal mammary vessels, result in hemorrhage which invades the anterior mediastinum. Immediate death from pressure on the heart or lungs may follow.

Fractures of the manubrium are of two types: the usual transverse described in the pathology, and the splintered or sprain fractures

accompanying dislocation of the contiguous structures. With these may be placed the dislocation of the manubrium from the body, the upper fragment being depressed behind the lower and the periosteal tear remaining anteriorly. The ca:es of fracture during childbirth collected by Packard and Borland[1] were practically all near the junction of the two upper parts of the bone. If direct violence is the cause, there are usually fractures of the ribs or spine.

Fractures of the sternal body are near the middle, at, or below the third interspace. The line of fracture is also transverse for the most part but may be oblique. The displacement is as of the manubrium, the lower fragment forward (Fig. 151).

Fracture or dislocation of the ensiform process is very rare. This part seldom has bony union to the body of the sternum, and it cannot be fractured off except in aged people, and even in those cases it is doubtful if a permanent deformity would result. Hamilton records one case seen twelve years after accident in which the process pointed backward at a right angle and finally became symptomless. The elasticity of this small process permits bending, so that it tends to spring back into place when violently shoved out. I have seen two cases of loose xiphoid processes which were symptomless and probably followed traumata long forgotten. Persistent vomiting and dyspnea have been symptoms in some cases. The vomiting was probably caused by reflex disturbance of the peritoneum and pressure on the liver, like that found in small midline epigastric hernia rather than from any direct pressure on the stomach. Dyspnea is probably caused by pressure on the sternal fibers of the diaphragm. It seems impossible to believe that the phrenic nerves are pressed upon, as the displaced cartilage lies in the *midline* and below the level of the distribution of these nerves. A roentgenogram does not show an unossified cartilage. If a deformity persisted or gave symptoms, it could be reduced under anesthesia if necessary; if manipulation failed, open operation to replace or remove the fragment subchondrally should be performed. Diaphragmatic and epigastric hernia must be differentiated.

Luxation of the ensiform process in a twenty-three-year-old man was reported by Skillern.[2] The cause was a fall he suffered on a diving board six months before applying for treatment. He had pain in the epigastrium which was increased when he leaned forward. There was a depression present at the normal location of the process where the cartilage had been forced inward.

Symptoms and Diagnosis.—If direct violence has been the cause, the patient may have been aware of something breaking in the front of the chest. There is pain, dyspnea, local tenderness, and, if any displacement, a deformity of the breast bone. Deep breathing or an erect posture are painful, the patient preferring to let the shoulders droop, and bend forward slightly, breathing with the lower ribs and

[1] Boston Med. and Surg. Journal, April 20, 1875.
[2] Internat. Clinic, Philadelphia, 1914, xxiv, S. 11, p. 238.

abdomen. The overlapping of fragments may be visible or palpable, unless there is great swelling. Deformity, crepitus, and mobility can be felt, or mobility of fragments may be observed during breathing. If hemorrhage forms beneath the skin, pointing forward, from a laceration of the anterior periosteum, the bone lesion may be disguised.

Fracture or dislocation caused by severe injury with pulmonary or other complications may be overlooked, or the hemoptysis, emphysema, or thoracic hemorrhage may be alarming symptoms. Local tenderness or a delayed ecchymosis are reliable signs in sprain or crack fractures without displacement.

Diagnosis must exclude contusion and congenital malformation or non-union of parts of the bone. Longitudinal fissures of the body, or seeming strange positions of the xiphoid which are congenital, must be considered. The Roentgen rays are of little value. Emphysema, hemorrhage, and other thoracic complications must be recognized, and accompanying injuries of the ribs and spine must be searched for.

Course.—Simple fracture or dislocations heal readily and usually by a fibrous connection. Bony union in the fractures of the manubrium is often seen. Displacement may not be difficult to reduce, but it is difficult to maintain. The overlapping fragments and moving chest, which do not favor bony union, seem to have little bearing on the clinical result. Ultimate functional union is explained on the basis that one layer of the periosteum is usually intact. The character of union is unimportant; if there are no complications, a permanent deformity or a non-union do not result in difficult breathing or other interference with function. Abduction and adduction of the arms may be interfered with to a certain extent in bad deformity or non-union.

Complicated cases with hemorrhage, emphysema, or with other accompanying injuries have a less favorable outlook. Injuries of direct violence often lead to pneumonia, or complications, and shock may cause early death, the mortality averaging nearly 30 per cent. Infection of the hematoma, osteomyelitis, or mediastinal abscess are late complications which are serious. I have seen one abscess of the anterior mediastinum following months after fracture. The pus may burrow forward between the fragments or come out laterally along the sternum. A small sinus gives insufficient drainage, and the process may extend into the pleural cavity, pericardium, or lung.

Open fracture and dislocation, especially injuries from gunshots, are to be classed with severe injuries. Hamilton[1] quotes one which tore away the sternum and exposed the arch of the aorta. Complete recovery followed.

Treatment.—Simple fracture or dislocation which has reduced itself demands little treatment except rest. The patient is put in a half-sitting position, an ice-bag is placed on the chest, and every freedom allowed the abdomen and lower ribs for respiratory purposes.

[1] Fractures and Dislocations, sixth edition, p. 184.

If displacement is apparent and painful, causing crepitus and pain at each inspiration, attempts at reduction are made by extending the spine and drawing the shoulders back during deep inspiration. This pulls upward the upper fragment and the lower fragment, or its attached ribs can be pressed on, until the deformity is overcome. As previously mentioned, this deformity is very likely to recur. Strapping with adhesive is not strong enough to hold the reduction. A pad placed between the shoulder-blades and a figure-of-eight bandage holding the shoulders backward may maintain the reposition.

If these methods fail, and the displacement causes no distressing symptoms, it may be left alone with little fear of complication. Objectionable deformity can be reduced by open operation. A convex incision along the outer border of the sternum permits the reflection of a flap down to the bone. A grooved director or periosteotome used also as a wedge may afford reduction when aided by pressure and traction. I do not know of any cases fixed by foreign bodies. The position after reduction must be maintained by the bandage or extension of the shoulders.

Abscess and osteomyelitis in the sternum should be treated surgically. Old deformities can be decreased by open operation by chiseling off of the new angle between the fragments. On the whole the simplest treatment is the best, and open operation will be rarely indicated. The complicated cases have a high mortality, and treatment is directed to saving life through combating those symptoms which threaten it. Operation for removal of fragments of bone to control hemorrhage or emphysema may be necessary.

FRACTURE OF THE LARYNGEAL AND TRACHEAL CARTILAGES.

The thyroid, cricoid, and tracheal cartilages are included.

Fracture of the thyroid cartilage is rare and ominous. In crushing injuries of the chest and neck, thyroid cartilage fracture may be frequent, but on account of the urgency of other more apparent injuries, or early death, they may be overlooked. Lane[1] mentions that out of 100 cadavers examined he was able to demonstrate 5 with fracture of the laryngeal cartilages.

The causes are direct violence from blows, falls across objects, hanging, and throttling. Muscular action may also become a cause in falls backward with the head hyperextended.

The mechanism of the fracture is pressure, exerted either laterally or directly backward against the vertebral column. Lateral pressure results in longitudinal fracture, particularly when the force has been applied on both sides of the neck. Multiple and comminuted fractures result from pressure backward. One cornu may be broken off by direct violence, as in a case reported by Stevens.[2] The man was struck by

[1] Pathol. Soc. Trans., London, 1885, xxxvi, 825.
[2] Guy's Hosp. Reports, liv, 233.

a fist while fighting, the right cornu of the hyoid was broken, and the superior left cornu of the thyroid cartilage was snapped off. The hyoid and inferior maxilla may be injured at the same time. Platt[1] described a double fracture of the jaw together with fracture of the thyroid cartilage in a fifty-eight-year-old man. There was a fatal termination in three days in spite of tracheotomy.

Symptoms.—The symptoms are convulsive coughing, cyanosis, and usually a copious expectoration of fresh, frothy blood. Swallowing is painful, and the voice is affected in varying degree from hoarseness to complete aphonia. The serious cases, which are opened into the trachea by rupture of the mucous membrane, are characterized by a subcutaneous emphysema of the neck tissues. If there has been complete separation of cartilage fragments, there is abnormal motility and crepitus together with extreme tenderness when the parts are manipulated.

Prognosis.—The prognosis is grave. Primary death follows from suffocation after an increasing dyspnea, emphysema or edema of the glottis. Delayed fatality is caused by pneumonia or hemorrhage. The mucous membrane of the larynx is always congested, and there may be a submucous extravasation of blood which spreads and involves the vocal cords. Matthews[2] has reported a prompt recovery from cartilage fracture. I have had one case which was complicated by large subcutaneous emphysema and secondary hemorrhage on the fifth day and which recovered. The emphysema persisted twelve days. The repair in the cartilage is probably by scar tissue in most cases, but later ossification takes place.

Treatment.—Treatment is symptomatic in most cases. The fragments can be returned to normal position by external manipulation, but if the symptoms of dyspnea are severe, an early tracheotomy is indicated. Attempts to reduce the fragments may start fresh hemorrhage into the subcutaneous tissue, or the mucous membrane may be torn by manipulation. There is then danger of emphysema and hemorrhage into the lung. Uncomplicated injury is cared for by local applications of cold, a sitting posture, and sedatives to relieve cough and anxiety. Where the emphysema is the most prominent symptom, its spread may be limited by light pressure pads or multiple incisions through the tissues. Laryngeal examination is not always possible on account of the patient's condition. If the hemorrhage is severe and tracheotomy has to be performed, the bleeding can be controlled by a laryngeal tampon inserted above the tracheal opening.

[1] Manchester Med. Chronicle, December, 1899, p. 168.
[2] Jour. Amer. Med. Assn., lv, No. 11, p. 943.

CHAPTER XV.

FRACTURE OF THE HUMERUS.

Anatomy.—The humerus is built as a lever for motion at both ends, almost unlimited in direction at the upper end, and for anteroposterior hinge joint motion with the forearm bones at the lower. Of necessity it must be able to support weight between the trunk and loads in the hands and arms. For that purpose it is furnished with powerful, stout muscles which protect the head, hold it firmly to the glenoid, and guide these motions. For practical purposes two epiphyseal areas must be considered: the upper in the head just above the site of the anatomical neck at the attachment of the articular ligament; the lower in the trochlea just below the attachment of the capsular ligament at the elbow. The upper epiphysis is a fusion of three ossification centres, one each of the head, of the greater, and of the lesser tuberosity and unites with the shaft about the twentieth year. The lower epiphysis represents a similar fusion of centres. At the elbow the epiphyseal centre of the capitellum appears in the first six months of life, the epitrochlea and head of the radius in the sixth year, the trochlea and the olecranon in the eleventh year, and the epicondyle in the twelfth year. Study of roentgenograms taken as early as six months of age show the shadows of the olecranon and coronoid fossæ, determining their position in the diaphysis. All these epiphyseal lines except that of the epitrochlea (internal epicondyle) have disappeared at the age of fifteen years. The epitrochlea does not unite completely until the eighteenth year.

The bone presents rather a thick compacta in its shaft and is almost triangular in section, whereas the head and lower end flatten out into a layer of compacta and closely meshed medulla of cancellous bone. At the extremities is strongly trussed cancellous bone, affording in the tuberosities and the condyles attachment for ligament, tendon, and muscle insertions. The lower end of the shaft of the humerus flattens out, narrowed in the anteroposterior direction and broadened laterally. The condyles form the lower extremity attached transversely to the anterior surface of the shaft and at a slightly oblique angle of 85 degrees. This accounts for the deviation outward, away from the body, of the forearm, to form the carrying angle. Also as the condyles lie in the front of the shaft, the extent of motion is not equal on both sides of the extended longitudinal axis of the humerus, but is greater in the anterior arc (Fig. 152). The two condyles, external and internal, guard the depressions in the shaft at their base, the coronoid fossa in front, and the olecranon fossa behind, which fossæ are made to

receive these two processes of the ulna. The external condyle articulates with the head of the radius by means of the capitellum, and the trochlea with its two lips allows hinge-joint motion between the internal condyle and the ulna. This motion would be present even in the absence of the radial head, limited by the lips of the trochlea, and, in case they were fractured, by the checking resistance of the lateral ligaments. The radial head besides articulating with the capitellum also rotate on its own axis in the movements of pronation and supination of the forearm, as in the ball-and-socket joint, quite independent of other movements of the elbow.

Above the two condyles are the bone tubercles for muscular attachment, the internal epicondyle (epitrochlea) on the inner side above the trochlea and the external epicondyle on the outer side.

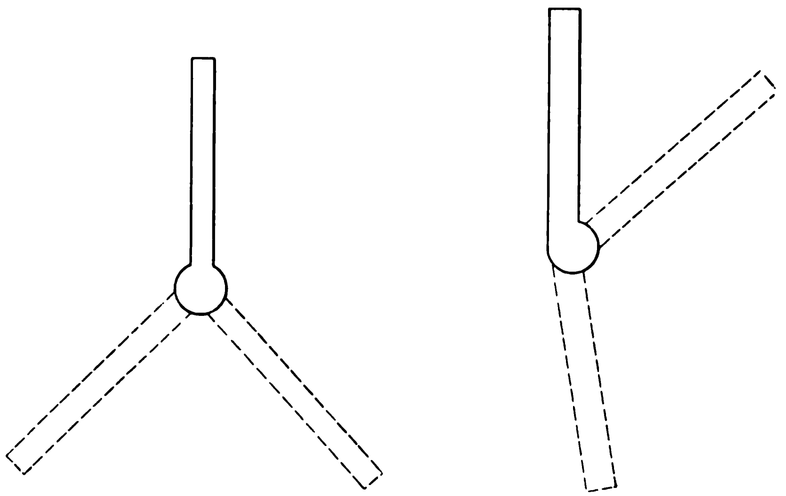


FIG. 152.—Diagram to show range of motion in elbow-joint. (Ashhurst.)

Ligaments at the Elbow.—The joint capsule of the elbow is attached above the coronoid and olecranon fossæ, blending with the periosteum of the humerus; on the inner side it is attached to the more prominent inner lip of the trochlea, so that the internal epicondyle lies without the joint. The external condyle and a very small portion of the external epicondyle are contained inside the attachment on the outer side. Below the joint the capsule is fastened to the ulna just below the ends of the olecranon and coronoid processes, and laterally along the margin of the greater sigmoid cavity of the ulna, and to the radius just below the orbicular ligament. Within the joint are the following structures: the coronoid, olecranon, and radial fossæ, the whole trochlea, the external condyle and a small part of the external epicondyle, the articulating surfaces of the coronoid and olecranon processes, and the upper radio-ulnar joint, which forms a diverticulum of the main elbow-joint.

The capsular ligament is unimportant as a governor of elbow motion, except through the strong lateral ligaments. The internal lateral ligament passes from the internal epicondyle with the flexor muscles of the forearm to the inner surface of the olecranon and coronoid processes of the ulna; the external lateral ligament from the external epicondyle to the margin of the lesser sigmoid cavity of the ulna, spreading out around the radial head and blending with its orbicular ligament. Supporting the external lateral ligament is the supinator brevis muscle, which is firmly adherent to it.

Ashhurst studied the limitation of motion in the elbow-joint.[1] In fifty children of both sexes below fifteen years of age, he found that the average flexion equalled 31.1 degrees; the limit of extension averaged 187 degrees or 7 degrees beyond a straight angle (180 degrees). This angle coincides with the hyperextension necessary to hold the arm at rest, when it is extended by the simple action of the ligaments. Further extension is limited by the impingement of the tip of the olecranon process behind, against the humerus, and by tension on the anterior and lateral ligaments and the overlying brachialis anticus and biceps muscles. In this hyperextension the head of the radius remains in front of the axis of the humerus (see Fig. 153).

FIG. 153.—Side view of bone of the arm in extension, showing the radius lying in front of the axis of the humerus. (Ashhurst.)

If force in the direction of hyperextension is applied, we have a mechanical problem arising similar to that arising at the wrist in falls on the hand. In children, whose ligaments and their insertions are relatively stronger than the bones in the juxta-epiphyseal areas, force of hyperextension causes a giving way of the lower end of the humerus. In adults, the bones being hardened and firm, the greatest stress falls on the anterior and anterolateral ligaments, especially on the inner side, causing them to rupture and permit a dislocation at the elbow.

Examination, Measurements, and Aids.—Injuries about the shoulder-joint or upper arm can be investigated by help of several simple expedients. If a flat object, such as a ruler, is laid along the outer side of a normal arm in its longitudinal axis, this ruler will touch the external condyle, lie flat along the arm, and extend beyond the shoulder without touching the bony parts of the scapula. This helps to determine the axis of the humerus. In the normal arm the head can be made out

[1] Fractures of the Elbow, 1910. p. 24.

in the glenoid, and by placing the thumb or finger on the anterior aspect of the head and rotating the shaft, one can feel the tuberosity and head roll beneath the finger and thus establish their normal position and continuity with the shaft. Measurement of the points

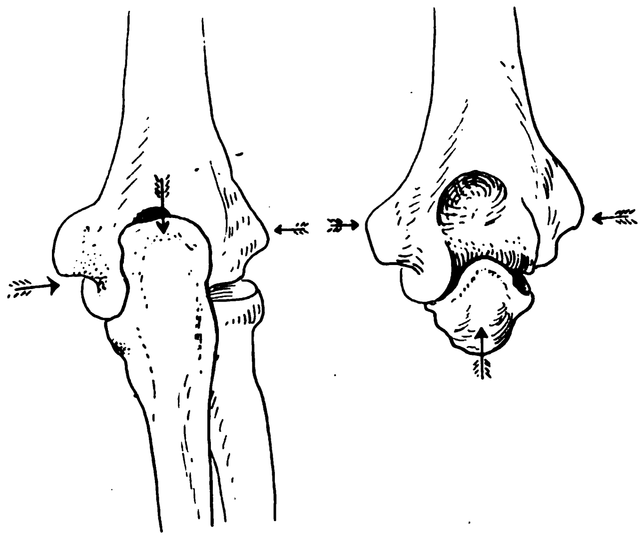


FIG. 154.—Illustration of the relative position of the bony points at the elbow in flexion and extension of the forearm.

from the coracoid to the external condyle of the humerus will give practically the same distance in normal arms. Variation of not more than one-quarter or five-sixteenths of an inch is allowed for individual

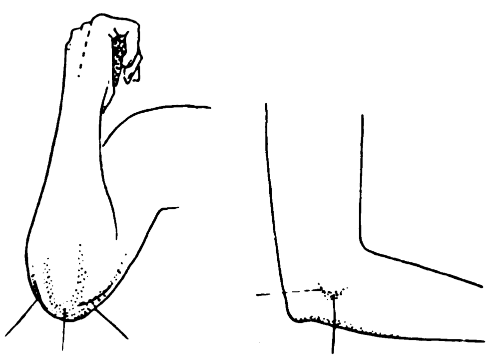


FIG. 155.—Illustrating location of bony points of the external condyle and radial head.

error, difficulty in localizing bony points, and natural differences in length.

When fractures of the lower end of the humerus and elbow are investigated, the bony points of that region must be compared with

those of the normal arm. The external and internal condyles, joined by the intercondyloid line, should lie normally nearly on the level with the upper end of the olecranon with the forearm in extension. In flexion the two points of the condyles and the olecranon form an equilateral triangle. In addition, on the anterior aspect of the forearm just below the external condyle, lies the head of the radius (Figs. 154 and 155), its rounded surface palpated best by a thumb or finger pressed here while the forearm is rotated. The position of the radial head does not vary regardless of the angle of the arm or forearm. If the ruler is laid down the back of the arm and extended beyond the elbow, it fails to touch the olecranon when the forearm is flexed.

The *carrying angle* is the term applied to the angle made by the forearm in its attachment to the arm. In normal individuals this is about 10 degrees outward away from the extended vertical axis of the arm. In fracture of the condyles or in the elbow neighborhood this angle may vary and become fixed, with corresponding loss of function. Because the carrying angle has much to do with the mechanism of elbow fractures, it should be correctly understood. Ashhurst[1] also made a careful study of this angle in fifty children and found that the average angle was approximately 170 degrees. In girls the angle was an average of 2 degrees smaller (168 degrees) than in boys, a natural provision looking toward the broader pelvis in later life. As mentioned above, this angle is not caused entirely by the angularity of attachment of the forearm bones to the humerus, but is also caused by the slight obliquity of the surface of the humeral condyles. That is to say that the total angle of 170 degrees is not made up of a right-angled joint at the end of the forearm bones (90 degrees) added to a chopped-off angle of 80 degrees at the lower end of the humerus. Each joint furnishes an angle of 85 degrees, making the total 170 degrees[2] opening externally. This angle formation is of great importance from the standpoint of alignment of the arm and forearm, for on account of the equality of these two angles the forearm in extreme flexion is folded directly over onto the arm, and their axes correspond. Consequently in full flexion the forearm axis does not cross the arm axis, and the hand does not come to lie on the chest, if the carrying angle is maintained, unless the shaft of the humerus is rotated inward. The position of acute flexion holds the elbow-joint extremely rigid, as the strong lateral ligaments communicate motions of the forearm when it is used as a lever, directly to the humerus, and if a position of abduction or adduction of the forearm is maintained while in acute flexion with a fracture of the humerus joint above the elbow, rotation of the lower humeral fragment will follow, and after healing a condition of cubitus varus or valgus will be frequent. Hence in fractures at the lower end of the humerus every effort should be made to maintain the normal position of the carrying angle,

[1] Loc. cit. [2] Potter, Jour. Anat. and Phys., 1895, xxix, 488.

and if the position of acute flexion is indicated in treatment as detailed later, the axis of the forearm should coincide with that of the arm and not fall to one side or the other.

In the series of all racture cases at Cook County Hospital for seven years it is found that fracture of this bone occurred in 5.7 per cent. of the total number, a proportion a little higher than that given by other authors, who usually place fracture of the humerus at 4 per cent. of all fractures.

Classification.—Fractures of the humerus are divided into those of the anatomical neck, surgical neck, greater and lesser tuberosities, and epiphyseal separations, of the shaft, supracondylar, dicondylar, condylar, and epicondylar.

The mechanism of shoulder-joint injuries, including anterior dislocation, fracture of the surgical neck, fracture of the acromion, dislocation of the outer end of the clavicle, fracture of the clavicle and of the tuberosity of the humerus is similar.

Hyperabduction and indirect violence are the causative factors in many shoulder injuries. They bear the same relation that forced dorsal flexion does to wrist injuries and lateral turns of the foot to ankle injuries

Because of tension on the axillary part of the capsule, abduction of the arm is permissible to a degree *only slightly more than a right angle*, if the scapula is fixed. If the scapula is rotated in the abduction movement, further abduction of the arm is possible, but when the limit is reached and the force acting continues, some part of the shoulder structures must give way; as in the wrist, either the capsule tears, or it pulls out of the bone surface if strong enough, or it remains entirely intact and the bone gives way. Thomas,[1] and many others have demonstrated that the first structure to give way in hyperabduction at the shoulder is the axillary portion of the capsule. As the action continues the tuberosity strikes against the acromion, and the head is forced out of the glenoid and the arm slides into a position of subcoracoid dislocation as it comes back again toward the body. Complete dislocation may not occur; laceration of the capsule, however, may be present. Other lesions may accompany the condition; that is, other portions of the skeleton may give way, and fracture of the surgical neck would represent a breaking of the lever (the humerus) with or without capsular tear and dislocation. This fracture would take place in the lever just below the point of the fulcrum pressure, where the bone impinged on the acromion. Other possibilities are the giving way of the fulcrum itself (the acromion) attention to which has been called by Mencke.[2] Fractures of the acromion not great in extent have been frequently found in shoulder dislocations. This fact would tend to confirm the suspicion that they are caused by abduction through the mechanism just described.

Another point in favor of a mechanism of hyperabduction lies in

[1] Jour. Am. Med. Assn., September 19, 1914. [2] Ann. of Surg., lix, 233.

strain on the greater tuberosity in instances of dislocation, either from tension by the capsular ligament or pull from the stretched spinati muscles, with resulting fracture of the greater tuberosity. These are frequent complications of dislocation, and the size of fragments varies from mere chips of bone when the ligament pulls out from its insertion, to large fragments when the insertions of the spinati muscles are also involved. The largest and best examples I have met with have been in subglenoid dislocations where the strain on the greater tuberosity is very strong.

If the acromion, acting as fulcrum in this mechanism, holds, and some of the force exerted is transmitted along its supports, the clavicle enters the field of possible injury through its close supporting position. Its outer end, being poorly attached, may give; if that holds, the bone may be fractured at its middle or outer third, where it is thin and poorly protected; or its inner end may be forced out of position, causing a dislocation at the sternal end. Thomas[1] reports 3 cases of upward dislocation of the outer end of the clavicle associated with anterior dislocation of the shoulder as evidence of a common mechanical cause, hyperabduction. The acromioclavicular joint is oblique from above downward and inward, and this angle favors the crowding against the clavicle by the acromion if it is pushed down. The ligaments may be torn, some pieces of bone chipped off, or the joint injured, as has been shown by Sievers.[2]

Fractures of the Anatomical Neck.—Pathology.—The pathology of fractures of the anatomical neck varies (Figs. 156 to 160). The head may be completely detached from shaft and rotated about on its axis or even driven through the ruptured capsule into the axilla. Some of the periosteal attachment may persist, holding the head on the neck, or the force of injury may jam down the head and its soft cancellous bone on to the neck. Much blood is effused, and the joint capsule, if unbroken, is greatly distended, so that one finds much limitation of movement, severe pain at first, and crepitus, if the broken surfaces are unimpacted.

Examination.—Measurement being taken from the bony point of the coracoid, which is found to be firm and painless, to the external condyle, shows, as a rule, no shortening of the arm. The axis of the humerus remains normal, and frequently there is a certain arc of passive movement which is painless and the patient can make some use of the arm, but function is impaired in direct relation to the force of the violence received and the displacement of fragments. Swelling may cause a simulation of a dislocation, but by Duga's test and the examination of the length of arm and humeral axis this can be differentiated. Duga's test consists in the surgeon placing the hand of the injured arm on the opposite shoulder and then pressing the elbow against the chest wall. If this can be done, no dislocation is present; if it cannot be done, dislocation is diagnosed.

[1] Loc. cit.

[2] Deutsch. Ztschr. f. Chir., cxxix, 583.

Firm pressure over the head, when the arm is grasped at the elbow and rotated, reveals a point of great tenderness and may elicit crepitus.

Fig. 156.—Fracture of the anatomical neck with rotation and impaction of the head fragment.

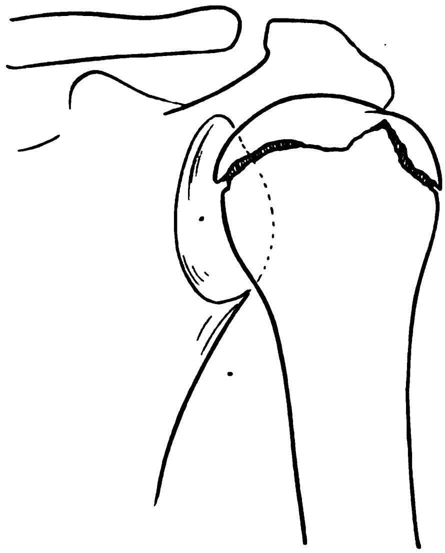


Fig. 157.—Fracture through the upper epiphysis and anatomical neck involving the greater tuberosity. Little separation.

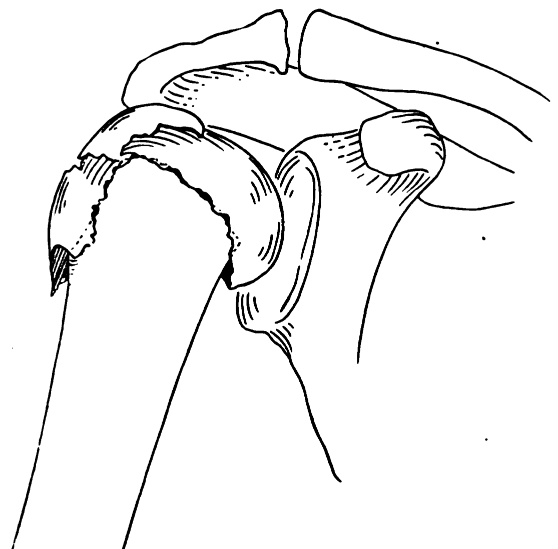


Fig. 158.—Fracture of the surgical neck and greater tuberosity with rotation and impaction of the upper fragments. This type of fracture leads to considerable restriction of motion in the shoulder if the fragments are not aligned and immobilized for a long period.

If impaction is suspected, as little manipulation as possible should be undertaken, that it may be preserved and the circulation in the head

FIG. 159.—Fracture of the anatomical neck, loosening of the greater tuberosity and impaction with abduction of the lower fragment.

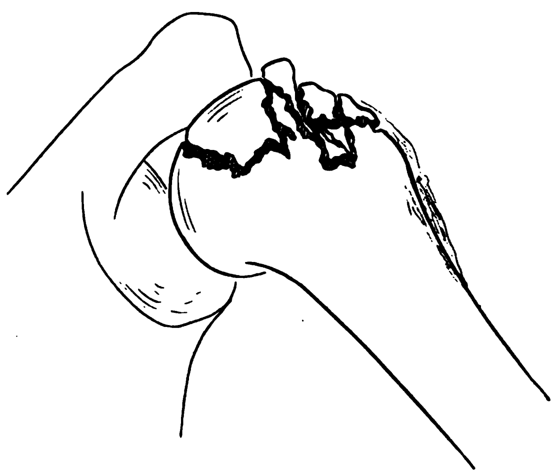


FIG. 160.—Comminuted fracture of the head and greater tuberosity from direct violence. Note the formation of callus along the outer side of the bone where the periosteum has been raised by a hematoma.

maintained for nourishment. For a positive and complete diagnosis a skiagram is imperative.

In impacted cases, or where the head is not widely separated or

rotated, the callus arises largely from the lower fragment and may result in thickening of the neck, adherence to the capsule, and the formation of exostoses, if spicules extend out into the joint structure. In a large percentage of these cases considerable limitation of motion in the shoulder-joint results, especially in the direction of abduction and rotation outward. Where the healing process has occurred without immobilization and with irritation callus from use and motion, the axillary vessels and plexus branches are sometimes adherent to the mass at the neck. Non-union in these fractures may be caused by four different factors: (1) by insufficient immobilization; (2) by failure to bring the broken shaft into contact with the head, which by rotation may offer a smooth surface to the neck with interposition of periosteum or capsule; (3) by necrosis of the head; and (4) by the individual's failure to throw out callus. The old distinction of intra- or extracapsular is not so closely adhered to as formerly, and is of importance only as it concerns the blood supply of the head or the interposition of fragments of capsular ligament which prevent union.

Treatment.—Treatment varies according to the amount of displacement.

When the head is in fair position and impacted, support of the arm in a Velpeau or Desault sling is sufficient, with complete rest of the shoulder from four or five weeks to avoid excess callus from irritation. When they are painless, passive and active motion should be started and carried along in increasing amounts each day, *but always stopped short of pain.*

If there is no impaction and the position of the head can be satisfactorily determined, the shaft and neck should be swung out at such angle of abduction and rotation that they will meet the head, and this position should be maintained by a proper axillary pad. A shoulder cap of moulded leather or heavy cardboard, or a moulded plaster splint which extends up the entire arm on to the neck should be added. The axillary pad should be generous in size and not the usual small wadded-up bit of cotton. The Stromeyer cushion is the best. It is large, fits properly against the curve of the chest wall, is thick enough really to support the arm in abduction, and on account of its firm attachment to the chest will not slip down (Fig. 161).

If the head is rotated clear around and its broken surface turned upward, the arm must be placed in extreme abduction and elevation, the patient being in bed with a weight of three to five pounds applied with plaster straps (Figs. 162 and 163).

Formerly after non-union in this class of fracture, a common occurrence, open operation was done, and the head, generally necrotic, was removed. If the upper fragment is detached long enough to become smoothed over, there is not enough left to freshen, and it must be excised. Through early diagnosis and attempts at coaptation of the fragments many of these heads can be saved. When the head is removed, the neck becomes rounded off, and the new shoulder joint

functions fairly well. Operation early, not after a wait of four weeks, as advised by Curtis,[1] with pegging on of the head by means of ivory, bone or metal nails, gives best results. It may be necessary to open the joint capsule and to attach the head to the neck by kangaroo tendon with no other fixation. The arm is put up in an abducted position. In this operation a lateral exposure through the deltoid fibers can be made.

Buchanan[2] says that the entity of fracture through the anatomical neck with dislocation of the head fragment has been recognized for a hundred years, and yet there are but 34 undoubted cases on on record and 9 unverified cases. He added 1 case in which the head was dislocated below the glenoid and was removed by operation. The result was that active abduction was possible to 45 degrees, passive to 90 degrees, and swinging movements of the arm were good.

Fig. 161.—A cheap and easily made wooden splint for abducting the arm in ambulatory patients.

Of all cases of fracture dislocation on record up to 1908, 12 were not operated on, 3 had the head returned to the glenoid by open treatment, and 14 involved excision of the head. Six cases gave no clinical history. Malgaigne, in 1855, Bell and Spence, in 1863, and Bennett, in 1880, all believed that dislocation first occurred and that the sharp edge of the glenoid acted as a wedge against the head of the bone and sheared it off. This opinion was strengthened by the frequent finding in old dislocations of a groove in the head caused by pressure of the glenoid rim, about which more will be said under Dislocation of the Head of the Humerus. Shortly after Buchanan's paper, Mason[3] collected 63 cases of dislocation complicated by fracture of the neck of the

[1] Ann. of Surg., 1900, p. 291.
[2] Ibid., xlvii, 659.
[3] Ibid., xlviii, 672.

humerus, which he added to the 117 cases of McBurney,[1] making 180 in all. Mason's collection showed 37 fractures of the surgical neck

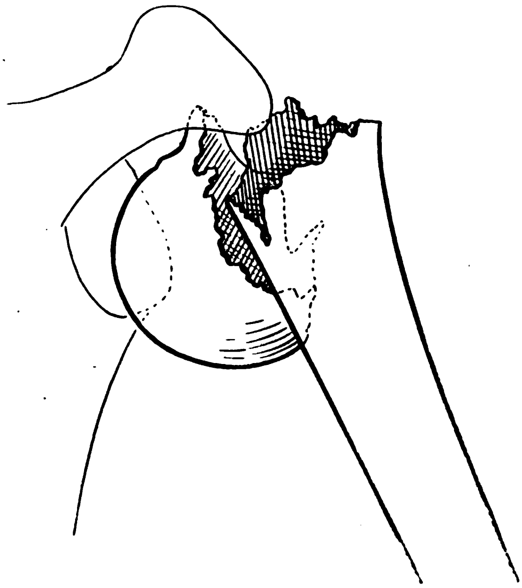


FIG. 162.—Fracture of the anatomical neck with extreme rotation and dislocation of the head fragment. Extensive capsular tear is expected. If reduction cannot be made by elevation and abduction of the arm, operation is indicated.

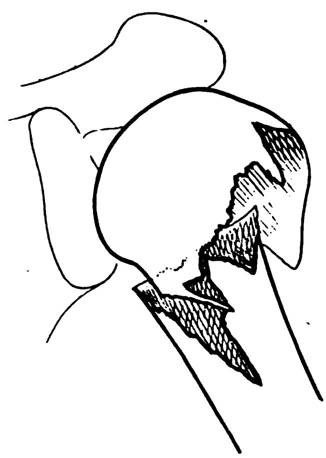


FIG. 163.—Fracture of the neck extending down into the region of the surgical neck. Lower fragment rotated inward and adducted.

and 26 of the anatomical neck. The dislocations accompanying were divided into subcoracoid 31, subspinous 2, subglenoid 11, and 19

[1] Ann. of Surg., 1894, v, 399.

not stated. Manipulation was reported as successful in 7 cases, 3 of which recurred, and as unsuccessful in 37. The treatment of the 63 cases was arthrotomy and reduction in 23 instances, 14 of which (60.8 per cent.) gave good results. In 21 instances resection of the head was done, giving 9 fair results (43.8 per cent.). To allow the displaced head to become united in malposition to the neck and then to attempt reduction is a worthless procedure. Buchanan believes excision of the head is the operation of choice. He cites 14 cases from the literature, in which 2 results were excellent, 6 good, and 1 moderately good. There were 2 deaths. The literature also contains a report by Syms[1] of a man aged twenty-seven years, who sustained a fracture of the upper end of the humerus with dislocation of the head from the glenoid. The head was removed, the shaft replaced within the capsule, and motion started after the fourth week. In discussing the report, Gerster inquired why the head had not been nailed on in accordance with Murphy's advice. Nassau recorded a case operated on after a year of fracture dislocation in which the shoulder was ankylosed and much atrophy of the arm muscles was present. He used Kocher's posterior incision, resected the acromion, and took off three inches of the humerus, used early massage, and got a fine result. Müller reports operation on a similar case, a female, aged sixty years, whose humerus he had fractured while attempting reduction of the dislocation. Functional result was good.

Five cases are reported by Shands[2] and Royster,[3] in all of which the head was removed with but poor results except in one case. Downes[4] reported a case in a four-year-old child in which all efforts to reduce failed, and at open operation a nail was driven in line of the head and shaft through the coraco-acromial ligament with the arm abducted 45 degrees. In three weeks the nail, which evidently protruded through the skin intentionally, was removed and the result was good. Mr. Robert Jones[5] states that he has roentgenograms of over 40 cases of fracture dislocation. When manipulation fails he extends the arm perpendicularly and manipulates the head into position.

Old cases with restricted motion do not promise well. To expose the field, an anterior incision with severance of the tendon of the pectoralis major muscle about three-eighths of an inch from its insertion is the best. This is the same approach used in old dislocations of the head of the humerus.[6] At the bottom of this opening one can identify the axillary vessels and plexus; if they are adherent to the torn capsule or callus, they can be carefully freed by sight with dissecting done close to the bone and the neck cleaned of its excess callus. The head is either removed or straightened, and by a suturing of the pectoralis muscle with mattress stitches to its tendinous insertion the

[1] Ann. of Surg., lviii, 574.
[2] Am. Jour. Orthop. Surg., viii, 389.
[3] Jour. Am. Med. Assn., August 10, 1907.
[4] Ann. of Surg., lvii, 282.
[5] Proc. Roy. Soc. Med., December, 1910.
[6] Andrews, Surg., Gynec. and Obst., i, 385.

wound can be closed except for a capillary drain at the lower end. Capsulotomy should not be overlooked as an aid in allowing freedom of motion. If parts of the capsule are removed or if it is opened widely, regeneration quickly follows. Good results after open operation on old cases are rare on account of the long-standing pathology and the patient's unwillingness to attempt and repeat motion after operation. Compared to final results after attempts to break up adhesions under anesthesia there is much to be said in favor of open operation, and the risk of tearing important axillary structures is far less when the open work is done. If the head is shoved down into the axilla or the case is an old one which on axillary palpation reveals a large bony mass and has much restriction of motion, operative interference is indicated. If impaction has occurred, this should be preserved, unless the head is in very bad position of rotation on its axis, so that when healed it will interfere with shoulder motion or become adherent in a detrimental manner to the other important structures. These cases are much better treated by open operation than by blind attempts to manipulate the head into position on the neck.

Kocher's posterior incision to expose the shoulder-joint starts in front at the acromioclavicular joint, runs down over the acromion and scapular spine, and then curves toward the lateral aspect of the chest. The acromioclavicular joint is exposed, and after the acromion is drilled for the wire to hold it later, it is separated by a saw. The deltoid fibers are laid outward, the joint capsule being thus exposed. The anterior approach given previously has the advantages that no bone has to be cut into, and that the important structures, nerves and vessels, are in sight and can be avoided. In the posterior methods these lie beyond and in front of the head of the bone, deep in the wound.

Fractures of the Surgical Neck.—These may be oblique, transverse, or serrated, with large, jointed fragments either in the front or back, usually in front. The bone breaks below the tuberosities to which the muscles are attached, and hence the head is somewhat rotated and abducted. This injury results from direct violence or severe indirect violence and torsion on the arm or elbow with the muscles above in tense contraction. The shaft is drawn inward by muscular attachment of the pectoralis and teres major and latissimus dorsi, while the biceps, coracobrachialis, and deltoid draw it up (Figs. 164 and 165).

The vessels or nerves in the arm may be seriously injured, and examination shows shortening of the arm. The head lies in the glenoid; the shoulder is not flattened, but there is a depression below where the shaft joins, unless there is great extravasation of blood. The axis of the shaft is directed inward, and the elbow is out from the body. Passive rotation of the arm with the surgeon's finger at the neck of the humerus gives distinct crepitus and is very painful, and the head does not move with the shaft unless it is impacted (Figs. 166, 167, and 168).

Shortening up to one and a half inches varies with the displacement.

If the fracture is impacted much less shortening, no crepitus, and not much change in the humeral axis is expected. If there is impaction and the fragments are well wedged together, immobilization in a

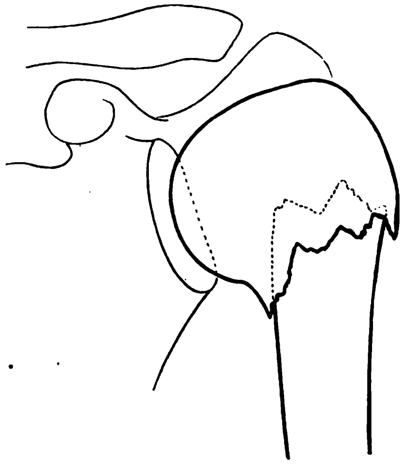


Fig. 164.—Fracture of the surgical neck; impacted head fragment abducted.

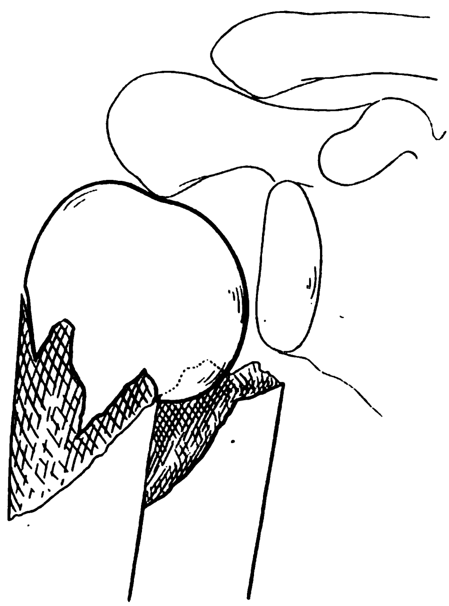


Fig. 165.—Fracture of surgical neck of the humerus. The shaft fragment is abducted and rotated in by the attached muscles.

sling and shoulder cap, with axillary pad or coaptation splints may be sufficient treatment. If much shortening or overriding is present, attempts at reduction can be made with the danger to the brachial

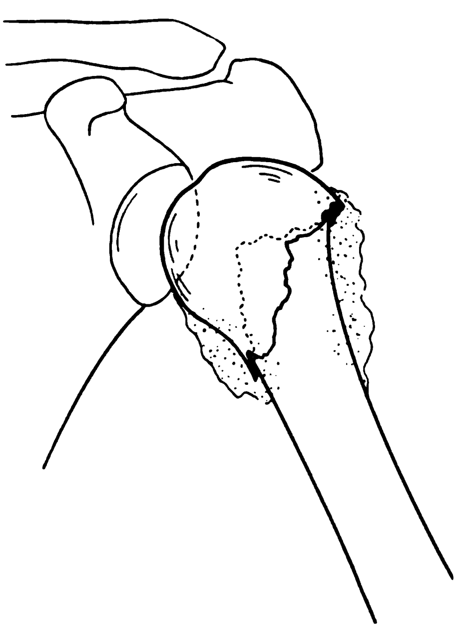


FIG. 166.—Healed fracture of the surgical neck. Note the large amount of callus, the angular deformity, and the ease with which abduction of the arm would be restricted.

FIG. 167.—Fracture of the surgical neck in a child. There is impaction, splitting and abduction of the upper fragment.

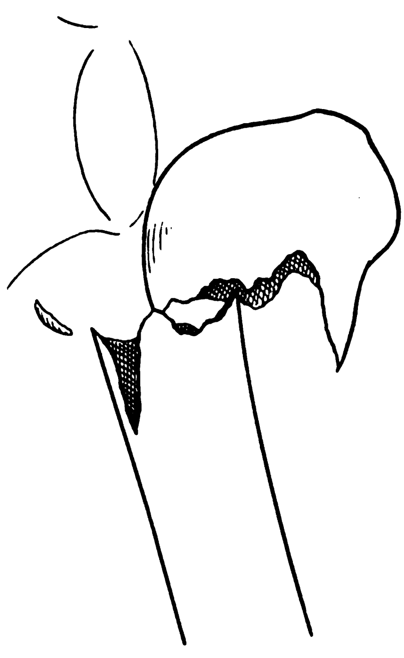


FIG. 168.—Fracture of the surgical neck with the greater tuberosity remaining attached to the head fragment. Shaft drawn inward.

vessels and nerves in mind. The Middledorpf triangle is an excellent dressing, if good reduction can be made.

When adjustment of the fragments is not satisfactory and anesthesia is contra-indicated or open operation is refused, treatment by continuous traction with a weight will give good results in some cases. Extension is made by adhesive strips applied along the anterior and posterior surface of the arm from the shoulder to the elbow (see Fig. 169). The hanging of a weight of five or ten pounds on this will

Fig. 169.—Treatment of fracture of the surgical neck by continuous traction. The triangular portion of the wooden splint is attached lightly to the chest and the arm cannot slide down into the box regardless of the position the patient assumes.

allow the patient to be up and about; or he can be kept in bed. When in bed, extension is lost unless applied with the patient on his back. If the head fragment is rotated badly and the shaft has to be placed in extreme abduction and elevation to meet it, the patient *must* be kept in bed, extension applied over the whole length of the arm, and weight hung on. The general rule is for the attendant to bring the shaft, over which he has control, in line with the upper fragment, devising such means of holding that position as each case warrants (Fig. 170). These fractures lead frequently to non-union and must be given five

or six weeks for healing. A large callus is the rule, and frequently circulatory and nervous disturbances of the arm are late complications. When callus has appeared after three weeks, the arm can be taken out of its dressing daily and carefully massaged for its circulatory good. When union is firm and use is started, to obtain free shoulder motion, the patient should be instructed to carry weights with the arm and should try each day to abduct and elevate the arm a little more, resting it against a door or wall and using the body weight to force abduction. If the fragments cannot be brought into apposition and maintained there by these means, plating or pegging by intramedullary bone splint driven up into the head should be considered.

FIG. 170.—Fracture just below the surgical neck. Note the angularity and apparent shortening of the arm.

Brickener[1] suggests a method of slow, continuous abduction traction for shoulder disabilities and limited function. The patient lies in bed well supported by pillows. The arm on the affected side is abducted as far as it can be comfortably and is then fastened to the head of the bed by a muslin bandage about the wrist. The head of the bed is elevated on blocks, and as the patient's body gradually slides down, the arm becomes more abducted and elevated. This position is acquired painlessly and gradually as a rule, and is merely a manner of forcing abduction when the patient will not take active exercises for that purpose. It may require a week's time to obtain a full result.

[1] Medical Record, New York, lxxxvii, No. 1.

If the traction becomes irksome or painful, it may be loosened for awhile or applied only at night.

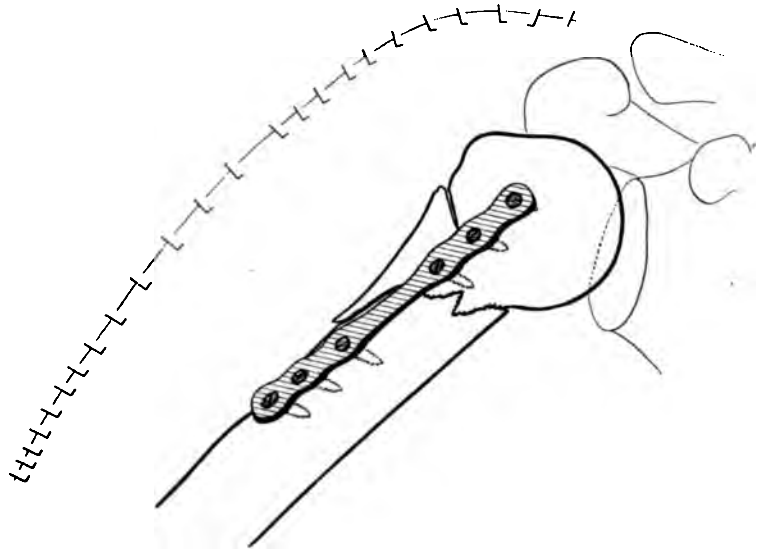


FIG. 171.—Postoperative picture after application of a plate for fracture of the surgical neck. A loose middle fragment has been included under the plate. Skin clips indicate skin incision.

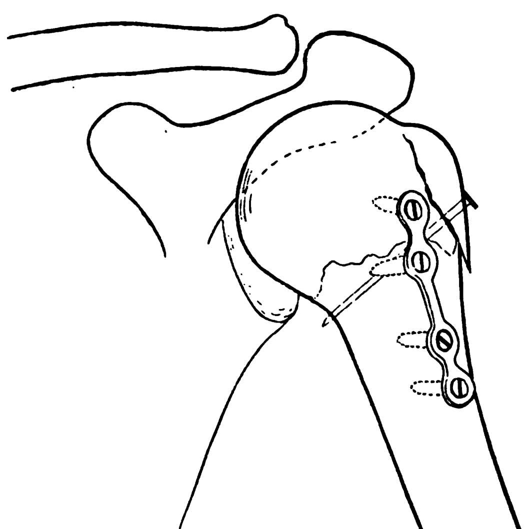


FIG. 172.—Plated surgical neck fracture. It was necessary to use a nail to attach the separated greater tuberosity.

Open operation for plating or intramedullary splinting in this region gives excellent results. Care must be taken of the circumflex

nerve. Usually no matter how dovetailed the fragments are they can be fitted perfectly together. After-dressing consists in a Middledorpf triangle or a moulded plaster applied gutter fashion on the lateral side of the arm, with the forearm in flexion and midway between pronation and supination. This allows the arm to be in a comfortable position and in abduction to favor the replacement of fragments.

The prognosis, as a rule, is good. There may persist some shortening or limitation of shoulder movement, but the scapula makes up for much of this, and the function should be good. Many weeks of persistent attempts at use, with massage, are necessary before a final

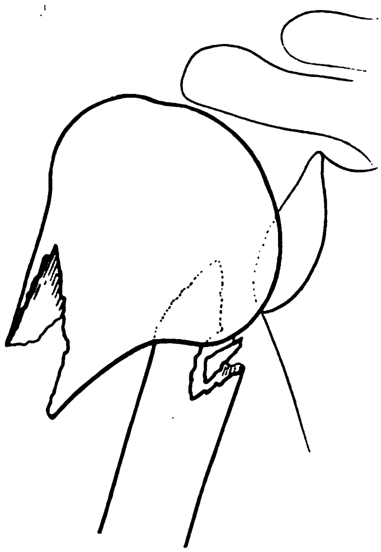


FIG. 173.—Surgical neck fracture before reduction. Note displacement and shaft rotation.

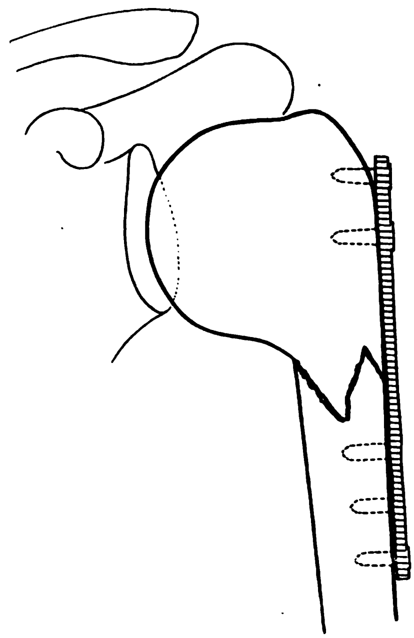


FIG. 174.—Operative reduction of the preceding fracture. The picture seems to be of the other arm, one from the negative, the other from the print.

stage is reached, and in children even the most unpromising cases may function very well in later years. Operative cases should receive particular attention in regard to after-treatment, that they may secure an earlier good result and avoid muscular atrophy about the upper arm.

Separation of the upper epiphysis occurs in children and young adults as a result of direct violence or in combination with indirect violence. Displacement is of varying degree. The line of separation follows the epiphyseal line closely, leaving the head and tuberosities in the upper fragment. In this fragment is a concavity, and the lower fragment is convex on the end so that the displacement is in many

instances limited to slight separation with no lateral movement. When indirect violence is combined in the cause, the shaft is generally so impacted that on examination the head may rotate with the shaft. There may be little crepitus on account of the soft character of the bone at this site, and the whole neck feels full with a prominence on the forward and inner aspect of the shoulder. The head is felt in the glenoid and other signs of dislocation are lacking.

The treatment of this condition is most important. If the head is not replaced, it may become necrotic, and will certainly interfere with growth. This epiphysis unites last and is the most important area in growth of the arm; *it should be replaced* in every instance. This may be accomplished by manipulation with the arm in abduction and rotation to meet the physical findings and the evidence furnished by the skiagram. Subsequent care is as given for fracture of the neck, with complete immobilization for four weeks and partial for three weeks more. In the partial period passive motion and massage without pain are indicated.

A series of 11 cases of injuries of the upper end of the humerus, which simulated birth palsies, was reviewed by Peltesohn.[1] Five of these were true Erb's palsy, and 6 showed bone injury of the upper epiphysis of the humerus. A typical case of false birth palsy showed a rigid shoulder-joint, some inward rotation of the arm, and inability to raise the arm above an angle of 90 degrees. In most cases the arm was held in abduction of 30 to 50 degrees, and although there was no true paralysis, there was paresis of the shoulder-girdle muscles. The cases of true palsies showed no contractures and had free front and side movements, but there was true muscular paralysis and atrophy of the pectoralis major and shoulder-girdle muscles. The diagnosis is made by roentgenogram. Peltesohn suggests that both shoulders must be taken for comparison, the position of the arms being maintained in the same degree of rotation, and the exposure must be instantaneous that movement may be eliminated. Examination of the roentgenogram demonstrates either a change in direction of the humeral axis or an abnormal distance between the end of the diaphysis and the clavicle. The whole epiphysis may be displaced outward.

In cases which have healed with displacement and deformity there is usually found a prominence of the enlarged epiphysis below the spine of the scapula. These old cases are treated by open osteotomy and correction of the axis of the lower humeral portion so that it makes alignment with the upper piece. Fresh cases in younger children are treated by elevation, abduction, and outward rotation of the arm.

If the head cannot be reduced or the reduction allows spicules or one edge to project over the shaft, open operation should be done, the head positively replaced, and any excess or projecting bone chiseled away. After this, one may hope for continued growth of the humerus and as little limitation in movement as possible. As little manipula-

[1] Berlin Klin. Wchnschr., June 22, 1914, p. 1162.

tion of the epiphyseal area as will reduce the displacement is indicated. Rough handling of the surfaces with instruments is not indicated; a narrow chisel blade cautiously inserted between the head and neck will be found of use as a lever to effect replacement of the soft bone. Simple replacement is usually sufficient, the arm being dressed in position to favor this. Foreign bodies except absorbable sutures are better left out.

Fracture of the greater and lesser tuberosities is not as uncommon as believed. It occurs from direct violence or more frequently from muscular action and indirect violence as detailed in the mechanism of shoulder injuries. Direct violence, a blow or kick on the shoulder, or a fall on the upper arm may act.

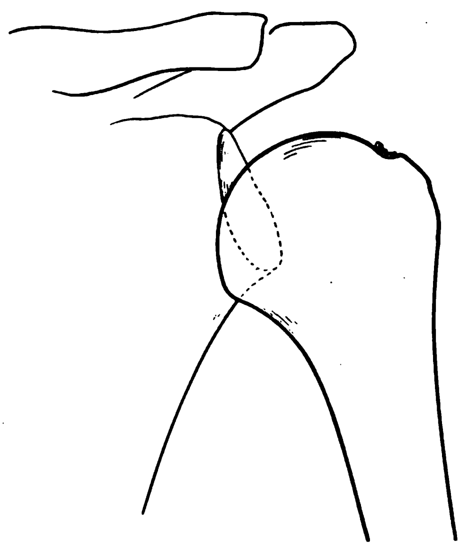


FIG. 175.—A slight fracture of the tuberosity caused by a pulling out from muscular action.

Muscular action, pulling out the tuberosity, occurs usually under one of three conditions: (*a*) In dislocation of the humerus; (*b*) with fracture of the neck; (*c*) with fracture dislocation (Figs. 175, 176, and 177).

The fracture is either complete or partial; the latter is more common. Careful skiagrams in anterior dislocation will reveal parts of the tuberosities pulled off in a surprising number of cases. At the Cook County Hospital I find an average of 15 a year. In 1907 Keene searched the different hospitals in Philadelphia and found 23 cases; among skiagrams for shoulder injuries Mason[1] found 21 in the literature complicating dislocation. Gibbons[2] reports a case from muscular violence alone, and Taylor[3] reports a case of fall on the

[1] Loc. cit. [2] British Med. Jour., 1909. [3] Ann. of Surg., xlvii, 10.

shoulder with no dislocation, in which there was an isolated fracture of the greater tuberosity. In the period before the introduction of

FIG. 176.—Ununited fracture of the tuberosity of ten months' standing. The greater separation was probably presented by some holding areas of periosteum.

Roentgen rays Gurlt (Knochenbrüchen) collected 46 cases from all sources, all but 2 of which were associated with other injuries, generally dislocation. Thirty cases were recorded by Melchior in eight years.[1]

FIG. 177.—A more extensive pulling out of the tuberosity by muscular action and direct violence.

The most complete separation of the greater tuberosity occurs in subglenoid dislocation, on account of the attachment of the infra-

[1] Beitr. z. klin. Chir., lxxv, 184.

and supraspinati muscles. In anterior dislocation the subscapularis may pull out the lesser tuberosity (Figs. 178, 179, and 180).

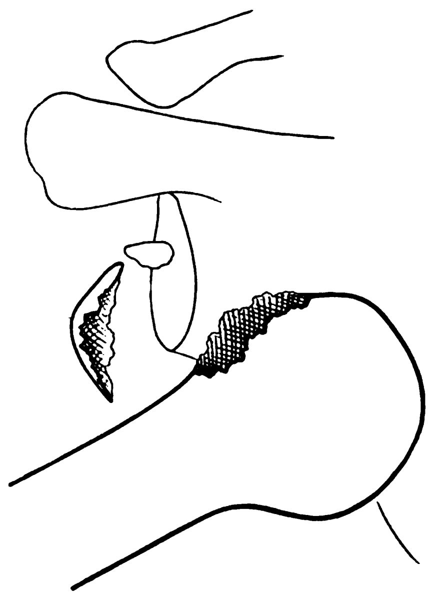


Fig. 178.—Subglenoid dislocation. Note the abducted position of the arm and the wide detachment of the fractured tuberosity.

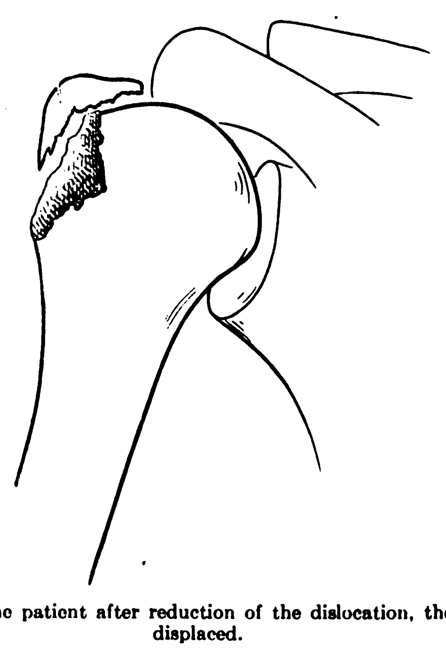


Fig. 179.—The same patient after reduction of the dislocation, the tuberosity is still displaced.

Study of the pathology reveals, pulled out from the head, the shell of bone, as large as one and a half by one inch, leaving behind it a sulcus in the cancellous portion of the head. The fragment is pulled upward and inward, and if skiagram is made before reduction of the dislocation in cases of that etiology, the displaced fragments can easily be distinguished at some distance from the head. In some instances this plaque of bone is comminuted, but is held together by its periosteum and muscle insertions. Failure in replacement leads to excess callus beneath the fragment, involving the spinati muscles, limiting movements of outward rotation, and by impingement against the glenoid rim above limiting abduction and elevation. When the separa-

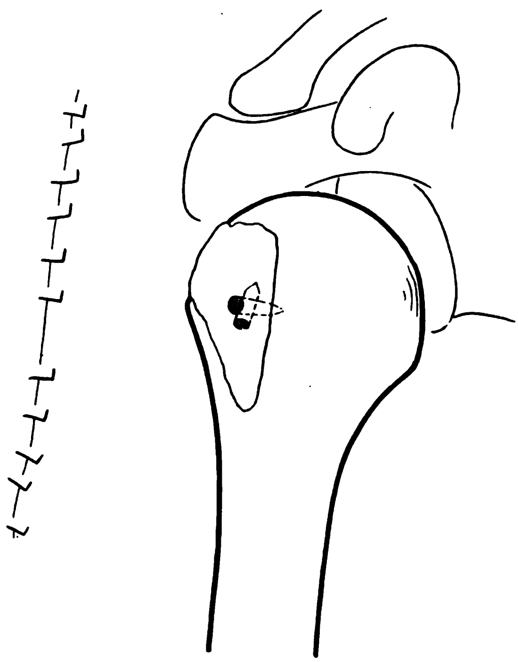


FIG. 180.—Operative repair of the fractured tuberosity shown in the two preceding pictures.

tion is not wide, but is complete, bony union may never take place, and a pseudarthrosis develops beneath the fragment, with disability in the motions mentioned. In cases of lesser degree union follows, as a rule, and the ultimate result is satisfactory, if the arm is immobilized long enough. Many cases are totally unrecognized. Ecchymosis is usually absent. Arm movement is limited to an unusual degree, more than is expected after simple dislocation, and while adduction may be normal or increased, abduction and outward rotation are very poor. Passive abduction is also limited, either by pain or by a wedging in of the fragment between the head and acromion, which locks the joint on movement attempted beyond a certain posi-

tion. If separation is but partial, the disability is not so great, but the recovery is prolonged, and there is permanent loss of function. That the fragment may be shown well, the roentgenogram should be made with the arm adducted and rotated outward, so that the shadow of the tuberosity stands out clearly.

Diagnosis is difficult without the Roentgen rays. When dislocations are reduced and pain and tenderness on the outer side of the head of the humerus persists unduly, and function is not normally established, this fracture should be suspected. In cases of extreme separation after reduction of dislocation, by bringing the arm in abduction and rotating with the thumb pushing down on the tuberosity, one can feel a crepitus and establish an acute point of tenderness. When complicated by fracture of the neck, roentgenogram alone will establish diagnosis.

Differential diagnosis must cover subdeltoid and subacromial bursitis, fracture of the anatomical neck, periarthritis, deltoid and circumflex paralysis, and in old cases, fracture of the glenoid. A guarded prognosis must be given in contusions of the shoulder which do not rapidly clear up, unless a good roentgenogram proves that no fracture exists.

Treatment by attempted reduction, with arm swung up over the head in abduction and maintained there, is the only method except open operation. To maintain the arm in this position for three weeks in order to allow bony union, with no positive information that the fragment is in place, is not very satisfactory. The surest and shortest method is for the surgeon to make an incision through the deltoid fibers on the lateral aspect of the shoulder, find the loosened and retracted tuberosity, fit it on the grooved area of the head, and insert a small nail or screw. Where the fracture is comminuted, two or more pegs may be needed. The arm should then be dressed in abduction with a moulded plaster splint from the chest wall up to the wrist, well padded throughout. Ten days in this position followed by a gradual letting down gives satisfactory results, with no excess callus and good shoulder movement. To operate on these cases and maintain the operative technic is difficult, but practice enables one to feel quite well by means of a blunt-pointed hemostat without putting fingers into the wound, and this operation can be done through a small incision. It seems unnecessary to add that when a fracture of the tuberosity is a complication of dislocation this latter should first be reduced, the fracture operation following. Phemister[1] advises operative approach from the rear by Kocher's method. He reports a case in which the fragment was fastened on by wire, and in which an examination of a loose piece removed showed its entire fracture surface covered with callus thicker than that over the periosteal and tendinous covered area. This finding would naturally be expected (Fig. 181).

[1] Ann. of Surg., September, 1912, p. 441.

Fracture of the upper end of the humerus complicated by dislocations is not very common. It is caused either by a continuance of the

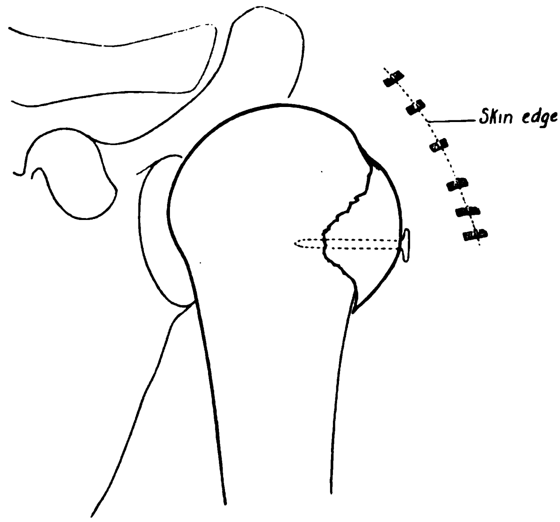


FIG. 181.—Operative repair of fractured humeral tuberosity by nailing. The skin clips indicate the skin and incision length.

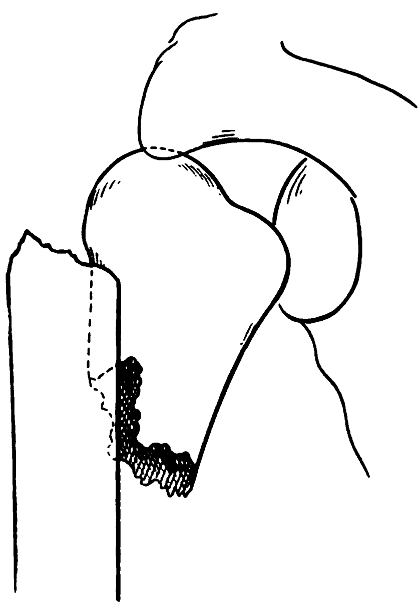


FIG. 182.—Fracture of the upper end of the humerus with dislocation of the head fragment which is turned completely out of the glenoid until the tuberosity points inward.

indirect force of the dislocation, which acts after the head has been forced out of the glenoid through the capsule and breaks the bone

in the region of the neck, or by direct violence. Such accidents may be a combination of direct violence received on the shoulder simultaneously with or after indirect violence causing dislocation (Fig. 182).

The displacement is usually complete, with the edges broken obliquely or serrated well up into the neck, and accompanying injuries to the nerves and vessels. Hemorrhage causes great and early swelling and masks the conditions on examination. No crepitus at all may be found. The arm is of usual length or slightly shortened, the axis of the humerus, that of dislocation, and the deltoid area flattened with its fibers under tension. The head may be palpated out of the glenoid, and muscular action, drawing the upper end of the shaft forward and inward, may cause an opening to the air from within outward. In severe injuries in this region with great swelling, this condition should be borne in mind, and before the performing of rough manipulation the possibility of harm to the vessels and nerves should be thought of. A skiagram should be had in every case possible and the position of the fragments carefully studied before attempts at reduction. Stereoscopic plates are of assistance.

Treatment should be under complete anesthesia. Attempts at reduction are made, first to get the head into the glenoid, and then to get the shaft in line, as in fracture of the neck. If ill-advised treatment is instituted with incomplete diagnosis, and the reduction of the dislocation is tried, great damage to the axillary structures may be done, especially if after failure by the Kocher method the stockinged foot is placed in the axilla and much force used in extension. Should the condition of the skin warrant, and permission have been obtained before anesthesia for open operation in case of failure of manipulation, this type of fracture should be operated at once to avoid complications. It is necessary to get the bone in proper place and hold it by silver wire, kangaroo tendon, or ivory peg. If much comminution exists, and there are loose fragments, they should be removed and apposition obtained by trimming of the large fragments before fixing with the means used. If these cases are not so treated, the head may become necrotic, callus may cause damage to nerves or vessels, and frequently a false joint develops about the upper end of the shaft which leads to a flail joint. Should the head be completely broken, it is best removed and the trimmed upper end of the shaft introduced into the glenoid, the neighboring muscles attached to it by bronze aluminum wire. After such reposition a new head may develop, and if the muscles are firmly attached, new tuberosities also appear, so that the ultimate function may be very gratifying. Great dangers are sepsis and nerve injury.

Fractures of the Shaft.—These occur at any point in its continuity and are caused by direct or indirect violence, torsion, and muscular action, as in throwing weights or balls, wrestling, sudden application of heavy force on the forearm and hand with the arm muscles tense. Twice the author has seen subcutaneous tearing of the biceps muscle

caused by sudden strain of heavy force on the hand, the brachialis anticus muscle and insertion holding, the humerus withstanding the strain, and the biceps giving (Figs. 183 and 184).

Pathology.—The pathology is varied. The line of fracture may be oblique, transverse, dovetailed from before back, or from the sides and splintered, with a separate piece of the shaft loosened. Impaction is rare. According to the site of the fracture and its character displacement varies. If the site is above the insertion of the deltoid muscle, the upper fragment is drawn inward by the pectoralis major and the lower fragment upward and outward by the deltoid; when below the deltoid insertion, the upper fragment is drawn outward, the lower one inward and upward and always with rotation of from 15 to 90 degrees (Figs. 185 and 186).

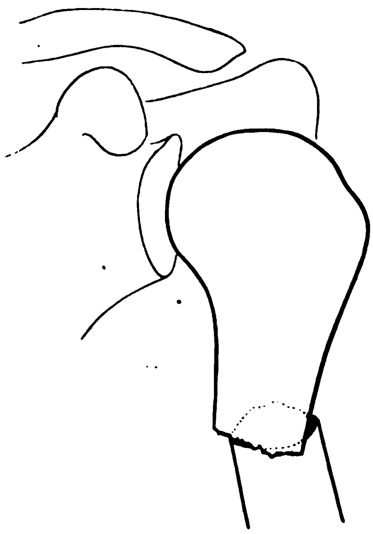


FIG. 183.—A transverse fracture of the humerus. There was a greater overriding present than is shown in the roentgenogram.

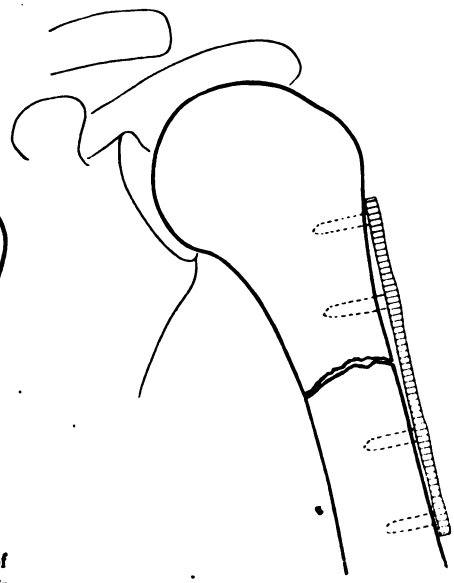


FIG. 184.—Repair of the preceding by a plate, a full length of arm obtained.

The examination reveals obvious fracture. The arm is shortened, a false point of motion evident, loss of function complete, and crepitus present. When the muscles are lacerated and a piece is drawn between the fragments, upon rotation no crepitus will be felt. As the fracture site approaches the elbow the displacement becomes anteroposterior, the lower fragment is drawn forward by the muscles extending to the forearm, and a splitting of the bone down toward the elbow-joint is common. Injuries of the great vessels are rare. As a complication, injury to the radial nerve in its course around the bone is the most common. It must be recalled that for over three inches of the lower half of the bone, this nerve twists around the shaft, so closely connected

with it that a sulcus is formed in the bone for its pathway and it is not imbedded in the soft tissues. Although this arrangement would seem to offer many chances for a catching of the nerve between fragments, the accident is really rare. Fracture at any point in this contact may unfortunately tear the nerve or contuse it so that its impulse-conducting power is temporarily abolished, or when the fracture heals, the nerve sheath may become entangled in the callus and when ossification follows, the nerve is pressed and its function

Fig. 185.—Severely comminuted spiral fracture of the humerus. The head fragment is drawn up and out by the deltoid, etc. Note the rotation of the shaft.

Fig. 186.—A combined spiral and oblique fracture of the shaft. The lower break involved the radial nerve.

ruined. Scudder and Paul, in 1185 cases of fractured humerus, report the musculospiral nerve injured eighty-six times.

This complication occurs chiefly in fracture of the middle third, next in the lower third, and least often in the upper third. Von Bruns's collection of 886 cases in 1886 showed 53 per cent. in the shaft, 22.2 per cent. in the proximal end, and 24.7 per cent. in the distal end. The later figures of Riethus[1] show 33.6 per cent. in the shaft, 35.4 per cent. in the proximal end, and 31 per cent. in the distal end in 319

[1] Beitr. z. klin. Chir., Tübingen, xxiv, 703.

cases of fractured humerus, of which 4.1 per cent. were complicated by musculospiral paralysis. Some instances of motor paralysis are not accompanied by a corresponding loss of sensation over the distribution of this nerve, a state of affairs which may be explained by the fact that the sensory supply to the radial half of the dorsum of the hand leaves the nerve above the usual point of involvement in fracture. Any age is liable to this injury. Vennat[1] reports 13 cases in children, in 3 of which there was complete division of the nerve.

Depending on time of appearance, the cases of paralysis are (*a*) primary, in which the nerve is damaged by the injury causing the fracture, or by the bone fragments themselves and (*b*) secondary, occurring during the healing process, from compression or stretching by the callus, or subsequent to healing from bone infection or pseudarthrosis. Loss of power in the forearm extensors may be partial or complete and follow immediately after the fracture or during the healing. Some degree of anesthesia, most marked on the dorsum of the hand between the metacarpal of the thumb and first finger, is the usual finding. The fingers assume a position of flexion at the metacarpophalangeal joint, with slight flexion and ulnar abduction of the wrist. The thumb is adducted and the forearm pronated. Should the sensory paralysis be extensive and follow the injury at once, rupture of the nerve above the middle of the humerus is probable.

In the secondary cases the callus begins to interfere with the nerve after the second week. Tinglings and sharp pains begin, and a slow functional failure develops, so that it is important at the early examination after fracture to ascertain that this nerve is intact. The sensory and motor disturbances begin simultaneously and atrophy or trophic changes are rare.

Prognosis.—Prognosis depends on the treatment and the length of time after injury that it is instituted. There are instances on record of recovery when operation was done as late as three and a half years after the onset. The improvement may follow within a few days after operation if the cause has been of secondary character, or may be delayed as long as a year, and Riethus[2] records 1 case of two years' duration. When there is both motor and sensory disturbance, sensation returns. If electrical reaction of complete degeneration is present, the outlook is more unfavorable.

Indication for operation is absolute in complete severance of the nerve, although there is no immediate pathognomonic symptoms so that many cases, especially of the primary type, are treated expectantly, until time shows no improvement. Von Bruns recommends operation if there is no improvement after four to six months. Many of the primary cases recover without operation. As the secondary type of paralysis does not occur spontaneously, it should be operated upon early, especially if the roentgenogram shows malposition of the bones and large callus. This early release of the nerve reduces the

[1] Monograph, Lyons, 1900.
[2] Loc. cit.

degenerative changes to a minimum and stops further progress of the paralysis. Scudder and Paul believe that all doubtful cases should be subjected to operation; that is, primary cases which improve and then suffer a recurrence during callus formation, or cases with an increasing paralysis, should be considered secondary cases. Stationary partial paralysis with partial reaction of degeneration may recover without operation. In the primary cases if one can be assured of continuity of the nerve, restoration of function will surely follow.

Treatment.—Treatment consists in freeing the nerve from adhesions or callus, resecting it if a scar has formed in its continuity, or it is so pinched that the axis-cylinders within may be crushed beyond recovery, and suturing the freshened nerve ends, with fine linen. It is rarely necessary to resect a portion of the shaft of the humerus to accomplish apposition of the nerve ends, and it is best not to disturb the bone at the time of the nerve operation for fear of causing further callus formation. The freed or sutured nerve should be supplied with a proper bed of fat taken from the immediate field or from the thigh or abdomen if absolutely necessary. The fat should be rolled around the nerve as a thick pad for a distance of an inch and a half on each side of the site of injury. At the Massachusetts General Hospital the end-results were obtained in 11 cases, 8 of which had no wrist-drop and 3 had no improvement, although 1 of these 3 was poerated on twice, the bone shortened by resection, and the bulbosu nerve shortened and resected. The longest interval before improvement was three years

Treatment of Shaft Fractures.—A favorite and efficient early dressing is a loosely applied coaptation splint on the padded arm. Care is taken to get the fragments in the best position by manipulation. This can readily be done without anesthesia. The forearm is steadied in a position of flexion, extension is made from the elbow, and by gentle rotation the shaft can be brought into line, the fingers of one hand guiding the fragments at the site of fracture. The splints should be carefully watched to avoid interference with circulation as evidenced by numbness and tingling in the hand and forearm, cyanosis and swelling of the hand, loss of capillary pulse in the nails or the radial at the wrist. The splint should be removed within a few hours after first application for inspection and to allow for the first swelling. These dressings may be supplemented by the Middledorpf triangle, which may also be used alone. If coaptation splints of padded wood or metal are used, or a moulded plaster splint, the forearm should be at a right angle, midway between pronation and supination, with the wrist suspended by a suitable sling from the neck. In applying such a sling the attendant may use either a folded broad piece of muslin or a broad bandage, taking a couple of turns about the wrist and fastening at the back of the neck. Knots at the back of the neck should be avoided, as they cause pain from pressure, and by pinning or by padding the neck the little irritation of bandage tension can be done away with. If moulded plaster

is used, and it is an excellent dressing, two pieces may be applied, one on the outer and one on the inner aspect of the arm from the shoulder and axilla to the wrist. These are bandaged on or fastened by adhesive. The author never uses a circular cast on fractures of the upper extremity; much damage has been done by them, to say nothing of their disagreeable weight. Volkmann's ischemic contraction may follow these fractures, and reference should be made to the paragraph on this in the section on General Pathology. If reaction is normal, union will be complete in five or six weeks, and thereafter the arm is carried in a simple sling for a short time; massage and motion follow, and a total disability of three months gives a useful arm (Figs. 187, 188, 189, and 190).

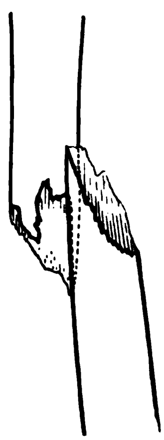


FIG. 187.—Spiral fracture of the humeral shaft. Note the rotation of fragments.

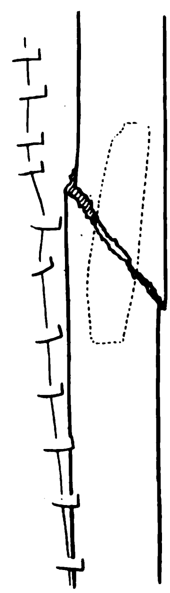


FIG. 188.—Operative repair of the preceding. Practically perfect apposition and correction of rotation.

The shaft of the humerus permits of relatively easy operative approach, and as this bone is the sole support in the arm and many cases of non- or malunion result from its fracture, open operation is frequently done on it. Incision is made on the outer aspect of the arm to avoid the nerves and vessels on the inner side. The bone is cut down and exposed with care to avoid the radial nerve if operating is being done at its level. In opening a series of these cases one is struck by the great displacement and rotation not evidenced in the skiagram, and in cases favorable for operation there results a perfect anatomical joining which other treatment cannot give. It is understood, however, that even in poorly treated cases, after years of work and use, nature makes a good bone, as shown by many specimens in

museums, in which alignment is good and callus absorption so great that little permanent evidence of the fracture remains. To get a quick, good joining, operation promises a sure return. If the fracture is serrated or oblique and reduction cannot be maintained, operation will give a shorter convalescence and a normally long arm. Application of the Lane plate is very satisfactory here, as in the shaft of the femur. Wiring is not done as much as formerly in shaft of this bone, but bone pegging with an intramedullary splint from the tibia has an advantage over plating in cases not too oblique, in that no foreign material is implanted.

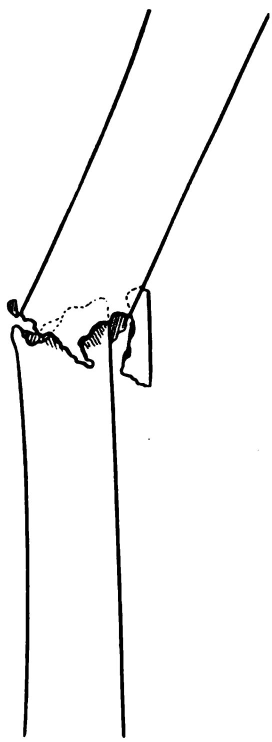


FIG. 189.—Transverse fracture of the shaft of the humerus by compression.

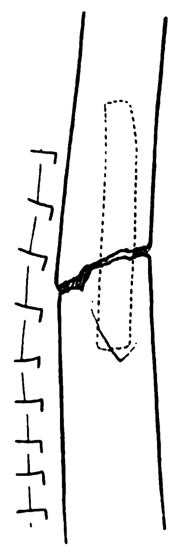


FIG. 190.—Operative repair of the preceding by an intramedullary splint.

As the humerus is the lone bone of the arm, when the fracture is open, the ends can readily be turned out (Figs. 191 and 192). The bone peg is inserted in the medullary cavity of one fragment after slight curettement, and then by manipulation it is snapped into the other end and the rotation corrected with almost perfect approximation and much firmness. A moulded splint is carefully applied over the closed skin in such a manner that the incision can be exposed and stitches removed without disturbance of splint or arm. Healing follows with a minimum of callus formation and a short convalescence.

25

Ununited fractures of the shaft occur. These are caused at times by constitutional disturbances, as mentioned in the general remarks and locally by the following factors: First, and most important, the arm is not properly immobilized nor for long enough time. The elbow should be immobilized with the arm, and the splint should

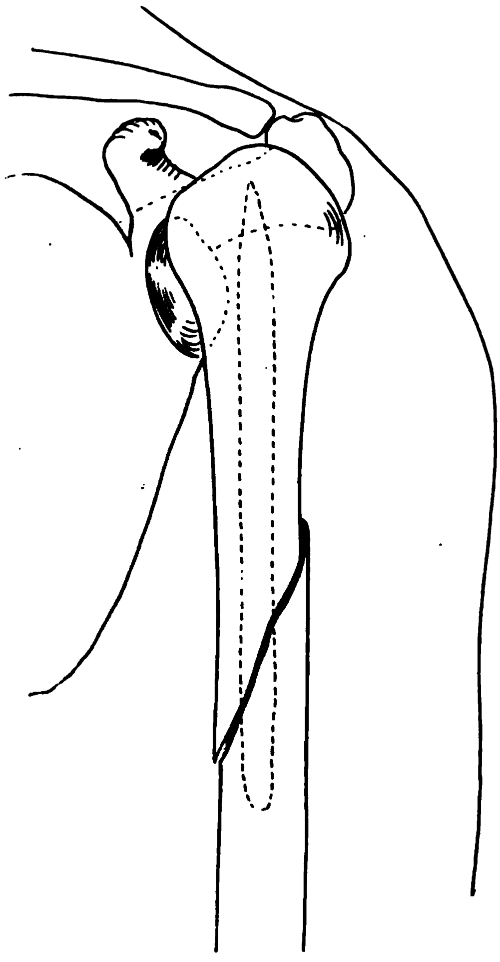


FIG. 191.—Operative repair of a very long spiral fracture of the humerus by means of an intramedullary peg. The plane of the fracture separation, extended much higher than the roentgenogram, shows and the bone peg was cut very long to give stability.

extend to the wrist. Coaptation splints used alone about the arm are likely to cause this condition, as the forearm frequently is left quite free and causes motion at the site of fracture by its movements. Second, the fragments are not brought into good position and callus formation is hindered. Third, fragments of periosteum or torn muscle find their way between the fragments at the time of fracture and are

not removed. Compound fracture, especially those produced by gunshots, are frequent causes of non-union. To apply dressings, to allow drainage, or to avoid pressure of splints in this class of cases leaves little immobilization, and if infection occurs or pieces of muscle get between fragments, non-union is apt to follow. In gunshots, when the humerus is shattered, chance for early bony union is less than in the forearm or leg, where a companion bone offers support as a splint. When failure of union develops, and the arm is swung in use, there appears after a few months a well-defined pseudarthrosis. If the

FIG. 192.—Healed wound of intramedullary transplant shown in the preceding picture. Note the alignment of the arm.

fracture has been a transverse or oblique affair, a capsular ligament forms around the broken end (Figs. 193 and 194), and a new smooth lining with free fluid develops. If the fracture has been comminuted, this new false joint may not be so well defined, but its structure is the same, and in cases operated, its dissection involves much work and time. One case here illustrated required an hour for the freeing of the sack of the joint, as the radial nerve ran down in its wall and on the inner side it was adherent to the sheath of the great vessels (see Figs. 195 and 196).

Treatment of ununited fracture in the humerus is purely operative.

Boring or drilling the ends is of no value, for as indicated above, the lining of the false joint must be completely removed to prevent recurrence. This false joint is carefully taken out by slow, sharp dissection and the ends of the bone sawed off to open the medullary cavity which has been sealed over by the joint surface to bring fresh

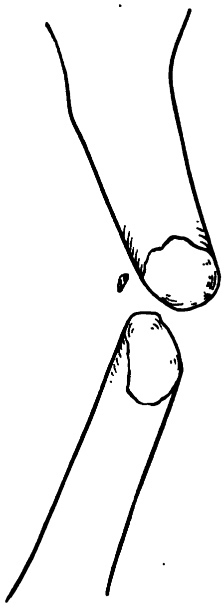


FIG. 193. — Ununited fracture of the humerus of nineteen years' duration. Note the rounded and eburnated ends and the closed medullary cavity.

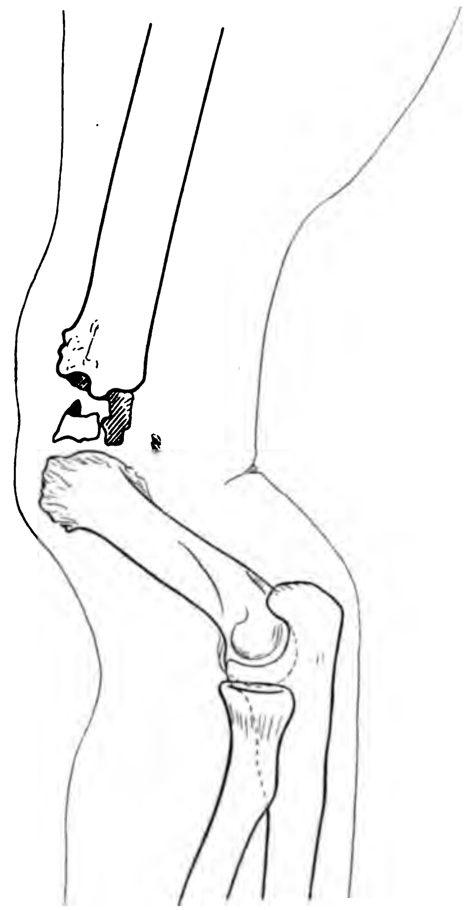


FIG. 194.—Ununited fracture of the humerus of a year's duration. This was completely cured by an intramedullary transplant of bone. See photograph.

bone surface in contact with fresh surface that union may be stimulated. If in doing this there is lost some length of the arm, an undesirable condition, the full distance can be maintained by cutting the bone transplant so large that it will have to be driven into the medullary cavity with a little force, and then the ends of the fragments can be separated to hold the former length, the intramedullary splint sus-

taining them apart and yet in alignment. Rarely this condition has to be supplemented by a peg driven through the shaft of the fragments to hold the intramedullary splint in place, but if care is taken to cut it large enough this will not happen. Bone or ivory pegs are better for this purpose than metal, which may lead to irritation and demand removal (Figs. 200, 201, and 202).

Fig. 195. — Ununited gunshot fracture of the humerus of seven years' duration. The dark masses are lead.

Fig. 196.—Repair of the preceding by Lane plate. It was found impossible to use either an inlay or intramedullary bone graft on account of the comminution of the lower fragment and its thinness.

A Lane plate is not indicated in this type of fracture, and much time and annoyance can be saved the patient by not attempting to plate but to use the intramedullary splint in the first instance. The plate does not hold firmly enough and will not allow for shortening caused by resection of the bone ends, as with a plate the fragments must be brought into apposition.

After intramedullary splinting, in closing the wound, care must be taken to maintain the position until the skin is sutured and the

FIG. 197.—Ununited fracture of the humerus. The scars of the original open fracture can be seen.

FIG. 198.—Presentation of the false joint in the arm when it is abducted.

arm firmly splinted from the neck to the wrist. This splint should be left on about six weeks, depending on the osteogenetic reaction and then a lighter moulded splint on the outer surface applied for

FIG. 199.—Ununited fracture shaft following gunshot seven years ago. Standing at rest scars on arm can be seen but no deformity to be noticed. When he attempted to raise arm the part above the non-union came up but that below hangs down helplessly as dead weight. No nerve involvement, as shown in the pictures of voluntary extension and flexion of hand and fingers, supporting weight of arm on other hand.

FIG. 200.—Ununited fracture of the humerus just above the elbow from an old open fracture.

FIG. 201.—The false joint of the preceding picture was repaired by an intramedullary splint (Ryan.) Note the alignment and flexing of the arm.

FIG. 202.—Same, showing extension of the arm. This man came into my service seven months later on account of a fracture of the tibia through the site from which the intramedullary splint was taken.

four weeks more. After this, if bony union is inaugurated, the arm can be kept in a sling for a couple of months and be supplied with daily massage and passive motion. These cases are very stubborn, and if the operation is undertaken to cure them, no effort or extra precaution of asepsis or immobilization must be spared in the after-treatment. Success should not be promised, of course, and the patient should understand the length of the postoperative care, but if the indication for each point in the technic is complied with, failure will rarely follow.

FIG. 203.—Mechanism of fracture of external condyle from fall on hand. (Ashhurst.)

FIG. 204.—Fracture of the humeral shaft with forward displacement of the lower fragment.

General Mechanism of Fractures of the Lower End of Humerus.—1. Falls on outstretched hand are the usual cause. The chief force is transmitted by the radius, through the carpus—the ulna does not articulate with carpal bones. Force is transmitted *via* the radius to the *external* condyle of humerus *via* head of bone and capitellum. For this force to reach the internal condyle it must first be transmitted to the ulna. This is accomplished by means of the interosseous ligament, the fibers of which pass obliquely downward from radius to ulna and act as a shock absorber (Fig. 203). If they passed in this direction from the ulna to the radius, such distribution of force would not follow. Hence falls on the hand lead to fractures of the external

condyle, or because the anterior and lateral ligaments hold and make the elbow-joint rigid, the humerus is broken above the joint transversely. Sudden hyperextension at the elbow produces transverse fracture of the humerus from the binding of the ligaments. If these ligaments are to be torn, it can only be accomplished by slow, powerful extension, and dislocation results.

As most displacements in the transverse fractures of the lower end of the humerus are of the lower fragment backward (Fig. 204), it is reasonable to suppose that the cause is not a simple thrust transmitted by the radius and ulna, for the condyles are set *forward* on the end of the humeral diaphysis and would naturally tend to be displaced forward. If hyperextension is acknowledged as the cause of these fractures, the transmission of the violence by the strong ligaments as described carries the lower fragment of the humerus backward. We know that these fractures are not caused by fall on the hand with the forearm flexed at a right angle, and that muscular power is not sufficient to hold the forearm flexed in such a fall, so that the mechanism by hyperextension as outlined is the usual one.

If we recall the anatomy of the carrying angle and its opening outward, we see that in falls on the extended hand the major portion of the strain falls on the internal lateral ligament, which, although stronger than the external ligament, is more frequently ruptured. The carrying angle also is a factor in fracture of the external condyle by direct compression through the radius.

2. Violence received in falls on the flexed forearm, or with the elbow in flexion, by driving the ulna against the trochlea, may fracture off the inner condyle of the humerus or cause olecranon fracture and anterior dislocation of the radius. Falls on the flexed forearm with the impact received on both forearm bones causes transverse fracture of the lower end of the humerus or epiphyseal separation. When the point of impact is on the acutely flexed elbow, if the arm is slightly abducted the blow falls on the internal condyle, which will be broken, and if the arm is held close to the body, the outer condyle suffers in a similar manner. Should supracondylar fracture result from fall on the flexed elbow, the fragment of the humerus can be carried forward by the ulna into the bend of the elbow, as described by Posadas. Fracture of the olecranon or radial head frequently accompanies this injury (Figs. 205 and 206).

3. Force applied on the outer side of the extended arm at the elbow in a fall to the ground with the extended arm beneath the body usually causes forced adduction of the forearm, pulling off the external condyle by action of the external lateral ligament or leading to comminuted supracondylar fracture.

Examination of Elbow-joint.—If examination is not made immediately after injury, several days may have passed in treatment by lotions or external applications. Swelling gradually subsides, and the elbow is useless, stiff, and painful and may not even be cared for by a sling. Inquiry into the history of the accident may reveal the type and

direction of trauma received, but in many instances, particularly in children, no definite information can be secured. Both the sound and injured arms should be compared, and the patient should be asked to move the injured elbow actively, if it is possible for him to do so. Usually the elbow is held stiffly, and the whole arm moves as a unit from the shoulder alone. Inspection may also reveal the deformity, the swelling, and ecchymosis, if more than twenty-four hours have passed since injury.

Palpation must determine if possible the location of the bony points, and it is wise first to examine the uninjured elbow in order to become

FIG. 205. — Transverse fracture of the lower end of the humeral shaft.

FIG. 206.—Healed repair of the preceding fracture. The alignment is good and the callus is not excessive.

familiar with the normal and to gain the patient's confidence. With the finger tips the subcutaneous border of the ulna can be traced throughout its whole length, including the olecranon. Then the radius can be palpated, its head recognized, its rotation with the shaft determined, and the position of the external condyle established. With these two points settled it is not difficult to find the more prominent internal condyle and to prove the other relations of the bony points compared to the normal. When these points are in normal position dislocation can be excluded, but not fracture; while if the points are abnormal, fracture, dislocation, or both may be present.

Careful palpation of the shaft of the humerus from above downward helps to determine the character of the injury and the position of fragments. Ashhurst advises also immediate tests for paralysis or anesthesia of the ulnar, radial, and median nerves.

Crepitus and a false point of motion can be detected by holding the arm (humerus) in one hand, the forearm in the other, and using gentle flexion and extension, then following by forward and backward or lateral rocking of the forearm held at a right angle. In supracondylar fracture the lower fragment of the humerus moves with the forearm. Crepitus may be found. To determine the loss of continuity in the humerus, the surgeon grasps the flexed forearm and uses it as a lever to rotate the humerus, to determine the movement of the diaphysis

FIG. 207.—Recent supracondylar fracture of the humerus. Note the apparent backward displacement of the lower fragment, the injury of the soft parts, and the patient's desire to hold the forearm flexed.

with the lower part, pressing a finger over the head at the shoulder, as in examination of the shoulder injuries. If no positive findings result, the condyles themselves can be grasped and manipulated by being rubbed together for demonstration of tenderness, crepitus, or false motion. If there is motion between them, and neither is attached to the shaft, intercondylar fracture can be diagnosed. The manipulations should not be rough; if the examination is systematic and gentle, little pain will result and no damage will be done, and fewer fractures will go undetected on account of impaction or poor examination. Anesthesia may be indicated for diagnostic examination, but the Roentgen rays are surer and less troublesome.

Supracondylar fracture, through the broad part of the shaft a couple of inches above the joint, is frequent and often followed by much

restriction of function. Causes are: falls on the hand or forearm with the forearm flexed, or direct violence received on the arm above the elbow. In practice at the County Hospital, Chicago, where the police bring injured malefactors, it is found that "gunmen," or the

FIG. 208

FIG. 209

FIG. 210

FIG. 208.—A very delicate complete supracondylar fracture in a child. Careful study of the roentgenogram demonstrates the complete plane of separation. The periosteum has been torn on both sides. This is not a green-stick fracture.

FIG. 209.—Healed supracondylar fracture. Dressed in extension which caused union with the angularity evident between the fragments. If the forearm had been folded over exactly on the arm, this angularity could not have occurred.

FIG. 210.—Dicondylar fracture. Note that the plane of separation passes through the olecranon fossa. There is callus beneath the stripped periosteum.

class of housebreakers who will murder, are subject to these fractures above the right elbow (Figs. 207, 208, and 209). These are received from a fall, a result of jumping from windows when caught, or as has been suggested, by the sharp tap of a policeman's hickory club. When the injury is healed the criminal can never again "pull a gun"

and shoot straight, as the use of the elbow has been greatly impaired and the carrying angle changed (Figs. 210, 211, and 212).

FIG. 211.—An open dicondylar fracture. The upper humeral fragment protruded through the skin. Both forearm bones fractured also.

FIG. 212.—Result obtained in the open fracture shown in the preceding. The forearm was later operated on for non-union in the radius.

Pathology.—The pathology is interesting. Infracondylar fractures occur in the flattened-out portion of the bone previously described, in which the line of fracture passes transversely from epicondyle to epicondyle (epitrochlea) with the line higher on the posterior than on the anterior surface of the humerus, so that the lower fragment is displaced backward. The trauma in these cases is received with the arm in extension, but rarely the lower fragment may be displaced forward, giving a fracture of flexion, as described by Kocher. Dicondylar frac-

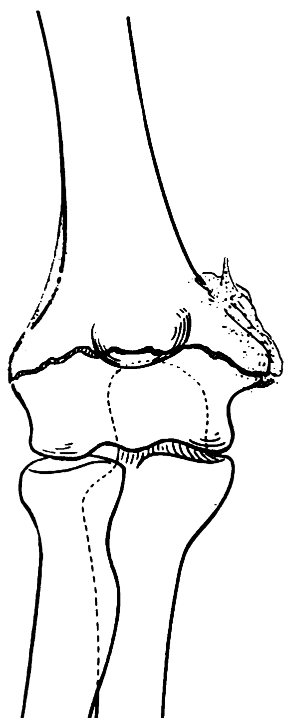


Fig. 213.—Dicondylar fracture. A good reduction with little extra callus around the internal epicondyle.

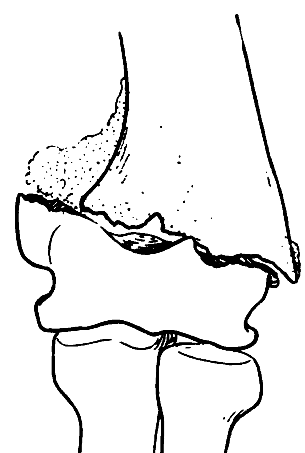


Fig. 214.—Healed condylar fracture. The reposition is less perfect than the preceding. Note the callus about the internal epicondyle.

ture (Figs. 213 and 214), called low supracondylar fracture by Stimson, has a similar transverse plane of separation which crosses the olecranon fossa, and is above the epiphyseal line. In this type lateral displacement outward or inward is more common than posterior. Chutro, quoted by Ashhurst,[1] reported 5 cases of an unusual type of dicondylar fracture first described by Posadas of Buenos Aires, in which

[1] Fractura de la Extremidad Inferior del Humero en los Ninos, Tesis, Buenos Aires, 1904.

the lower humeral fragment is displaced forward into the elbow, complicated by posterior displacement of the forearm bones. Chutro's cases all recovered with elbows ankylosed in complete extension. Ashhurst[1] reports 1 case which he recognized and operated on with a happy result.

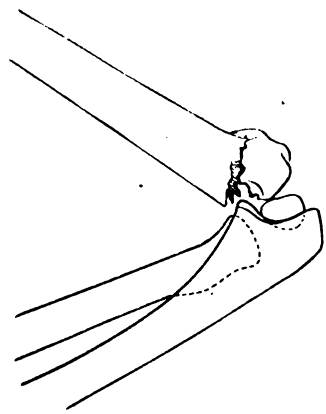


Fig. 216.—Dicondylar fracture in a child. Although the forearm is flexed, it is not flexed enough to cause complete reduction.

Fig. 215.—A good reduction of dicondylar fracture. Note the callus found beneath the stripped-up periosteum.

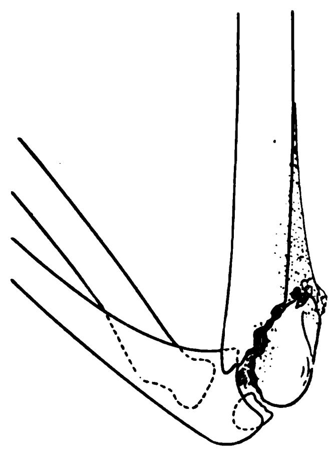


Fig. 217.—A less perfect reduction with more callus. Note that the plane of separation passes from before backward and upward.

If the etiology is indirect violence from the forearm, the lower fragment is usually pushed backward and held there by the contraction of the triceps muscle, the periosteal bridge, and the brachialis anticus and biceps, which pull the forearm up. The muscles of the forearm arising from the epicondyles retain the lower fragment in

[1] Loc. cit.

flexion when the forearm is fully extended. The olecranon is pulled upward, and difficulty lies in distinguishing this fracture from a posterior dislocation of the forearm bones at the elbow. The lower fragment may be displaced forward with either mechanism as a cause, in which case the sharp edge of the upper fragment can be palpated above the elbow, and the forearm seems lengthened. The lower fragment may be split down toward the joint with separation of the fragments, or a shell may be split off the anterior or posterior

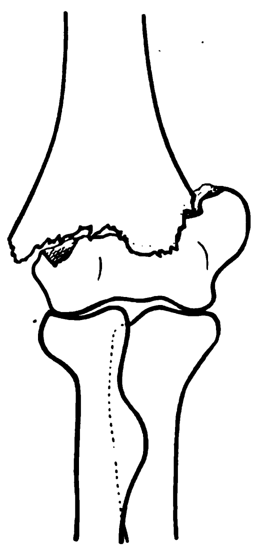


Fig. 218. — Dicondylar fracture with lateral displacement.

Fig. 219.—Dicondylar fracture with little displacement in a child. Note that the fracture plane is well above the epiphyseal line, the two epiphyseal centres just appearing below.

Fig. 220—Dicondylar fracture in a child.

surface of either the lower fragment or the shaft, complicating the break. Long strips of periosteum are lifted up in a similar manner (Figs. 215, 216, and 217), and if reduction is not complete callus may form beneath these and furnish great thickening of the bone with corresponding loss of function (Figs. 218, 219, 220, 221, and 222).

Diagnosis.—If the lower fragment is split, the line may be but a crack, or the case may merge into one of fracture of the condyles, or a T-fracture. The lower fragment separating into two or more pieces may be wedged apart by the lower end of the shaft, which pushes

down between them, and may come to lie in the joint, pressed against the ulna (Figs. 223, 224, and 225). If healing is permitted unreduced

Fig. 221.—Lateral view of green-stick dicondylar fracture in a child. Note that the incomplete plane of separation is almost vertical.

Fig. 222.—Dicondylar fracture in a child. Lateral displacement and impaction.

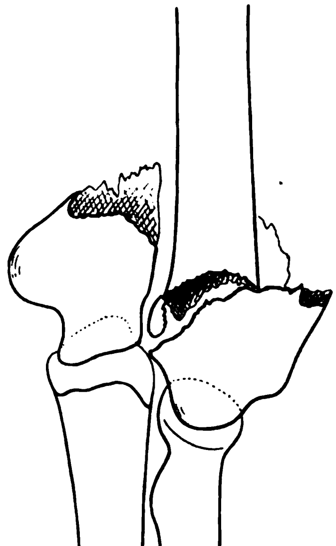


Fig. 223.—The fracture at the elbow opening into the joint. The upper fragment has been pushed down between the two lateral ones.

Fig. 224.—Repair of the preceding. One fragment nailed on by an ivory peg, the other wired in position. Incision on each side of elbow.

in this position, the arm is shortened, great thickening of the upper part of the elbow exists and probably also a complete bony ankylosis with the forearm fixed in a position established by the dressing.

For differential diagnosis refer to the expedients mentioned above. If there is simple supracondylar fracture, transverse or slightly oblique, with the lower fragment pushed backward and upward, the forearm appears lengthened, but examination reveals the following:

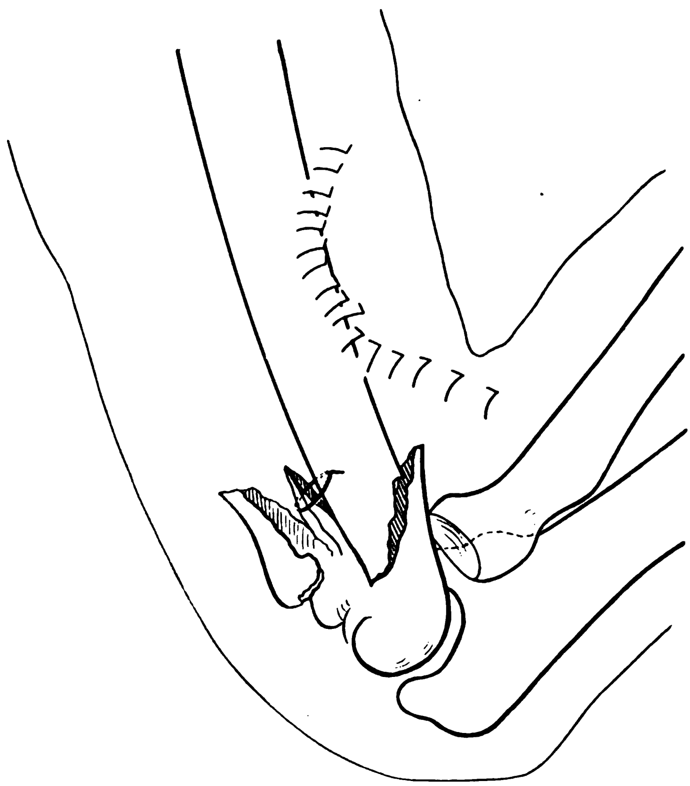


FIG. 225.—Lateral view of the repair. This does not look like an excellent result, but the shaft fragment has been removed from the joint. The functional result was fair to good.

1. The points of the olecranon and condyles are in normal relation; in dislocation they are not so.
2. The axis of the humerus is not normal, as evidenced by the ruler test.
3. The forearm is of normal length from the internal condyle to the styloid process of the radius; in dislocation it is shortened.
4. The arm is shortened from coracoid to internal condyle; in dislocation it is normal.
5. The deformity can be reduced but quickly recurs.

6. The lower end of the upper fragment is felt above the elbow crease in front.

7. Crepitus is usually present in fracture when complicated by a splitting apart of the lower fragment.

If in doubt as to diagnosis treat the injury as a fracture, not as a dislocation.

Positive diagnosis is very difficult on account of the great swelling. By waiting for this to subside and by finding increase in the width of the elbow posteriorly, with looseness of each condyle on manipulation and the bony projection of the upper fragment forward above the elbow, one establishes diagnosis. In supracondylar fracture this projecting edge of bone is rougher than in the dicondylar variety, which also protrudes less. This fracture involving the elbow movement is very serious on account of injuries to vessels and nerves and possible loss of blood supply to the hand. It is imperative that early diagnosis and treatment be instituted.

Treatment.—Treatment must aim to restore the fragments to position and relieve pressure on nerves and bloodvessels. Bony ankylosis must be considered from the very first, and it is best avoided by early and complete reduction (Figs. 226, 227, and 228). If the lower fragment is displaced backward, it may be pulled down and into position on the upper fragment by one's grasping the forearm and wrist pulling down, slightly hyperextending first but not enough to endanger the soft parts in front. This unlocks the fragments and permits reduction. An assistant makes counter-extension by pulling backward and upward on the arm, meanwhile pressing against the lower fragment to push it into position. When the lower fragment is split and the end of the upper shoved between its parts, this correction must then be aided further by pressing of pieces of the lower fragment together, but it is quite impossible to hold them in position by manipulation.

The lower fragment having been brought into line, its position is secured by flexion of the forearm as far as possible with the hand in full supination. It is wise when correcting the carrying angle in this process of hyperflexion, rotating the lower fragment on to the humerus, for one to abduct the forearm slightly, as a little overcorrection with resultant cubitus valgus is less noticeable and disabling than cubitus varus (Fig. 229). When the joint is so flexed the point of insertion of the triceps muscle is brought anterior to the longitudinal axis of the humerus, and while holding the lower fragment in a sling-like grasp, it also tends to crowd it into place. With an intact triceps the lower fragment cannot be displaced. The angle of fixation should never be less than 60 degrees, as this holds the fragments firmly together by means of the ligamentous structures and the soft parts, and no motion can take place at the elbow, although the shoulder is free for all movements. This position uses the fibers of the triceps tendon as a posterior splint, the tissues in front of the elbow pushing the fragment back against it. To maintain this, a moulded plaster splint from shoulder to wrist held together by adhesive is used—or the arm may be strapped up

FIG. 226.—T-fracture of the lower end of the humerus. Some retention of fragments in position.

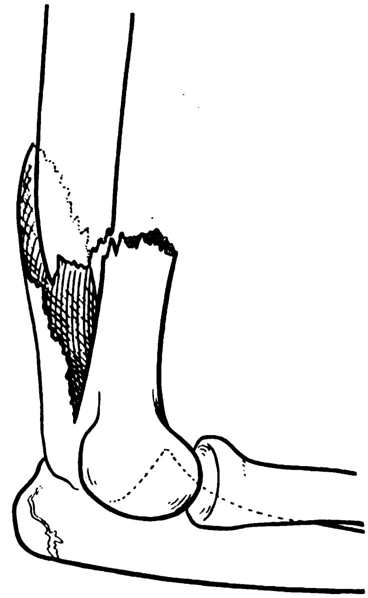


FIG. 227.—Lateral view of the preceding.

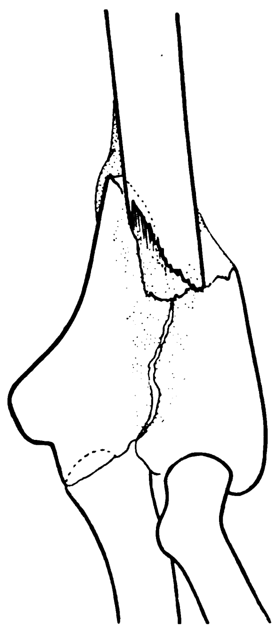


FIG 228.—Healed reduction of the preceding.

FIG. 229. — Healed T-fracture of the elbow. Note the new angle given to the forearm.

in this position by adhesive. A favorite adhesive-plaster dressing is one first applied about the forearm and then the arm with final turns encircling both and covering the elbow. The shoulder need not be immobilized.[1] Hartshorn[2] suggests an additional adhesive strip along the dorsum of the injured forearm, over the uninjured shoulder, to give the support of a sling. This makes the dressing snug but prevents shoulder motion, which can be safely enjoyed by means of a neck sling. Even with much swelling around the elbow, it is surprising how little this position of exaggerated flexion affects the circulation. Flexion must be held for four or five weeks at least; then the arm can be gradually lowered and given passive motion, but never beyond the arc which is painless. The extreme flexion can be lessened in favorable cases after ten or twelve days gradually and the arm brought to an angle of not more than 60 degrees. This type of fracture demands prolonged immobilization, the prognosis and final result depending on the simplicity of the break, its early reduction and proper immobilization. If motion is started too soon or carried beyond the painful point, irritation is set up which causes a great excess of callus with thickening and subsequent loss of motion or ankylosis. One needs but to try this treatment to become an advocate of it.

When the lower fragment is displaced forward, it should be reduced by traction of the parts below the elbow, with the shaft of the humerus pushed forward and then treated in the same position of flexion. Either an anterior or posterior moulded splint may be used, or they may frequently be combined to advantage in cases where long immobilization is wished.

Fractures of more than a couple of weeks' standing in which callus has already been deposited in the space beneath the periosteum stripped up from the shaft are treated under anesthesia. Forcible flexion and extension at the site of fracture is then done (arthrolysis), the callus broken loose, and after the lower fragment is forcibly refractured from the upper, it is brought into hyperflexion and overcorrected in abduction (valgus). If full flexion cannot be reached at the first trial, the attempt should be repeated in a few days, with more flexion at each trial until a satisfactory position is attained.

If these means are not successful, as in cases of long standing, open operation is done, and by osteoplasty the bone is cut through and replaced in good position, the arm being brought into the hyperflexed position. Supracondylar osteotomy is not performed so much for the disability of gunstock deformity as it is to correct the visible changed axis of the arm on esthetic grounds. An internal fixation splint is not always needed, but every possible bit of bone should be saved, and the periosteal covering should be allowed to remain intact in part of its circumference. Von Saar[3] has reported 6 cases of this character in 2 of which the radial nerve was entangled in the

[1] Lusk, Ann. of Surg., xlviii, 432.
[2] Med. Rec., New York., lxxxvi, No. 18.
[3] Deutsch. Ztschr. f. Chir., cxxviii, S. 29.

callus. Five of these cases were old; his results were very good in all.[1]

Operation is more often reserved for those cases in which the lower fragment is split apart and the shaft enters between the pieces, for T- and Y-fractures, and other irreducible cases. To approach, longitudinal incision must be made on each side of the elbow just above the condyles. By dissection the surgeon avoids the joint surface, either identifies the ulnar nerve on the inner side as it curves down behind the inner condyle and retracts it out of the way, or by going a little anterior avoids it as a source of worry. He exposes the fracture on both sides, may tunnel under the tissues in front of the elbow, keeping close to the bone with a dull elevator, and avoids important structures. The problem of bringing down the broken-off and separated condyles and attaching them to the end of the shaft then presents itself. By traction on the flexed forearm this may be accomplished, aided by bone-grasping forceps working in the wound. One side at a time has to be attached. The outer side may be brought down first and fastened to the shaft by a nail or ivory peg, then attention is directed to the more important inner condyle. The extension of the forearm, through the pull of its flexor muscle, makes traction on this condyle, and it can generally be worked into place and held there either by a wire into the shaft or a wire thrown around both lower fragments and binding them together. These fragments are also nailed together. The closer they fit and the smaller the fissure between them which opens into the elbow-joint, the less danger of bony ankylosis awaits. The position and avoidance of the ulnar nerve must be remembered at all times When the fragments are in position, they must be held there, and one should be sure that the carrying angle of the forearm is normal. The muscle and skin closure follows, after which the arm and forearm are stiffened into position by a heavy moulded splint which must pass down to the finger bases and give perfect immobilization in as much flexion as can be secured. If the displacement warrants, injured elbows put up in marked flexion are treated best because:

(1) When they are removed from the splint, it is easier to get the patient to exercise the arm in the direction of extension.

(2) If ankylosis or limited motion follows as a result, the forearm and hand are in a more favorable position for use.

(3) If stiffness and limited use follow, they are less apparent in a position of flexion.

(4) Advantage is obtained of the use of the tissues for holding the correction as outlined above.

8. **Fracture of the Condyles Alone.**—The internal condyle may be torn off by indirect violence accompanied by capsular and muscular action, and the external condyle may be broken by transmission of violence from the head of the radius, or by falls on the side with the arm abducted.

[1] Lexer, Zentralbl. f. Chir., 1913, No. 16, S. 603; Steinman, Beihelfte z. Med. Klinik, 1912.

These fractures vary in extent; a small chip of bone may be broken off, or the whole corner of the condyle extending well into the joint may be split off (Figs. 230, 231, 232, and 233). The inner condyle is most frequently involved on account of falls on the elbow with the arm extended to catch the body weight, the violence being transmitted through the ulna to the trochlea and a fragment split off. Children usually fall on the outstretched hand and hence seldom suffer this fracture. The line of fracture is oblique and is found extending from the epicondyles into the trochlea, with serrated and uneven edges. Injuries on the inner side are more extensive, as a rule, than those of the

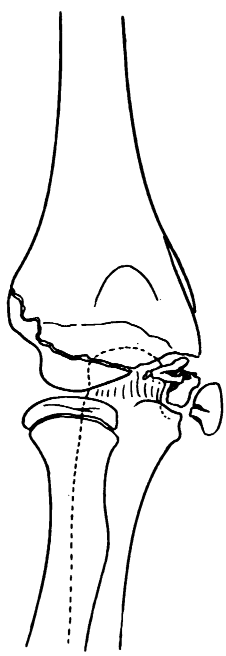


Fig. 230.—Comminuted fracture of the internal epicondyle part way through the epiphyseal line.

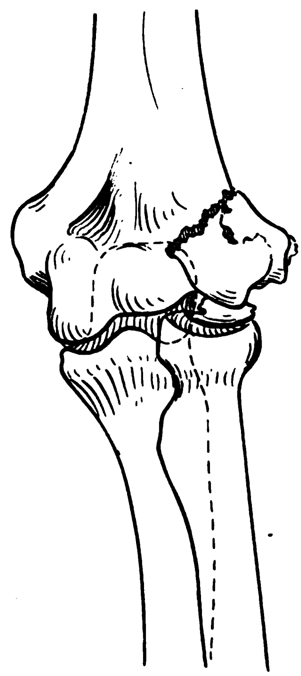


Fig. 231.—Internal epicondyle fracture in an adult.

external condyle. Because of the lack of support of the internal condyle, the broken-off fragment of which always ascends, the forearm is swung in toward the body by its own weight and the carrying angle disappears. Manipulation of the internal condyle causes crepitus. The oblique line of fracture enters the joint at any point as far laterally as the capitellum. The axial continuity between the humerus and the ulna is lost and in a corresponding degree the function of the forearm is lost, as the ulna is the bone which gives stability to the elbow, the radius being more concerned with the wrist and hand. The elbow-joint may be freely movable in any direction. When the coronoid or olecranon fossæ are involved, the resulting deformity simulates a

dislocation, but examination will reveal the loose fragments and settle the matter even if there is the customary swelling and ecchymosis. When the forearm is extended, it can be moved from extreme adduction to abduction, and crepitus is present.

Should a small tip of the epicondyle be broken off, it is pulled downward by its muscular attachment, the flexors of the forearm. In young adults this may be accompanied by a starting of the epiphysis, the displacement being slight. Where the condyle is broken off into the joint, the loose fragment is pulled upward and rides on the shaft of the humerus. In such displacement the olecranon seems more

FIG. 232.—Lateral view of internal epicondyle epiphyseal separation in a child.

FIG. 233.—Fracture of the internal epicondyle, displacement upward and forward.

prominent than usual, and it is pushed backward a little, while in front the broken edge of the humerus may be seen and felt. The ulnar nerve crossing just behind the internal condyle may be injured primarily in this fracture or may be secondarily involved from contusion with traumatic neuritis and consequent palsy of the muscles supplied by it. Late ulnar palsy may follow from callus compression.

Small detached pieces of the condyles, as a rule, heal to the rest of the bone and cause no trouble (Fig. 234). Under some circumstances by position just below the joint surface, especially on the inner side, they may interfere with flexion of the forearm, and when a large piece

into the joint is broken and slips upward, it may allow but slight movement of the joint. This is because the ulna is displaced upward with it, and if healed in that position, the forearm is in adduction. This is described as cubitus varus. The normal carrying angle is obliterated, and but little flexion, rarely beyond a right angle, is possible. When the external condyle is broken in the same manner, the carrying angle is exaggerated, the forearm is in greater abduction, and there exists cubitus valgus. Any degree of these deformities may exist, depending on the extent of the fracture in the condyle.

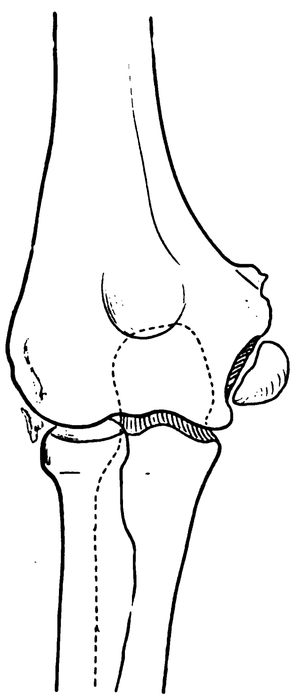


FIG. 234.—Ununited fracture of the internal epicondyle. There is evidence of callus formation about the external epicondyle and above the site of fracture.

Treatment.—Treatment of small fragments consists in replacement of the loose piece by manipulation and immobilization of the arm, the forearm in flexion, with pains taken to maintain the carrying angle by abduction of the forearm in fractures of the internal condyle. A moulded plaster splint posteriorly with a pad holding the fragment in place is good treatment. Results should be checked by skiagram. Fabian[1] describes 24 cases of fracture of the external condyle treated at Leipzig in the last three years; 9 were operated upon, 4 nailed, 1 had partial and 4 total extirpation of the detached fragment, all operations on account of functional disturbances and none for cosmetic purposes. As a result of his experience he favors total extirpation of the fragments.

Fracture of the internal condyle into the joint is difficult to reduce and hold reduced. These fractures are often caused by direct violence and are rarer than the best teachers formerly supposed. Ashhurst says that Chutro found but 2 in 106 cases, Monchet 1 in 17 cases, and Kocher 6 in 45 fractures of the lower end of the humerus. By complete extension of the forearm the condylar piece may be pulled down into place, but when the position is released, it slips out immediately. Serrated and locked edges make reduction by manipulation very difficult. Hyperflexion is the best position; with that the fragment can neither ascend nor rotate. Considering the possibilities of restricted motion and the danger of excess callus or ankylosis, many of these cases are best treated by open operation, particularly if the ulnar nerve is involved.

[1] Deutsch. Ztschr. f. Chir., cxxviii, 409.

The surgeon makes incision over the injured condyle in the long axis and avoiding the important nerve, he exposes the fragment. By grasping it with a forceps, extending the arm as a help, he can bring the piece into good position, unless the locking and serration cannot be overcome. When proper position is secured a nail or screw is driven through the fragment into the shaft of the humerus (Figs. 235 and 236). The arm is put up in moulded plaster in a half-flexed position for six weeks, and after-treatment follows the general rule of fractures near joints in regard to use and motion.

In some instances these fractures are not recognized and are insufficiently immobilized or otherwise mismanaged; then the condylar

Fig. 235.—Operative repair by nailing of broken-off condyle.

Fig. 236.—Side view of the preceding. The reduction seems fair but functional result was poor.

fragment remains loose and yet interferes with use of the elbow. Healing can take place with the fragment displaced, with cubitus varus or valgus, and as long as elbow movement is satisfactory, much may be overlooked in the way of deformity. For loose fragments, for excess callus inhibiting joint motion or interference with the nerve, operative treatment is indicated. Each case must be studied with good skiagrams to aid, and as little bone removed or such areas freshened and reapplied with an internal splint as the findings demand. Nerve involvement is very serious, and after operative freeing, many weeks of massage and electric treatment are needed to get effect. After an incarcerated nerve, as the ulnar, is freed, if there is not sufficient fatty or loose subcutaneous tissue present in the operative field,

a suitable piece of fascia lata with fat attached should be removed and wrapped carefully around the nerve. It is then tucked up out of the way of the callus by delicate sutures.

9. Fractures or separation of the lower epiphysis of the humerus are the result of falls on the elbow or forearm in children, the bone yielding across this softer area. Direct violence is also a cause, but it may act in conjunction with indirect violence transmitted by the bones of the forearm. In these separations the upper end of the radius and ulna are seldom broken. Force transmitted by them is expended through the insertion of the capsular ligament of the elbow-joint, which is firmly attached above the epiphyseal line. As in ankle and wrist fracture, the ligaments, especially in adolescence, are stronger than the growing cartilaginous epiphyseal area, and the latter yields when sudden force is applied. In early youth both condyles are included in the shaft portion of the epiphysis, and fractures up to twelve or thirteen years generally include both condyles, the shaft above being torn off in a rounded edge.

Epiphyseal separation is rare after fifteen years of age and is most frequent about the twelfth year. As the cartilage gives little evidence of separation in the roentgenogram, this separation is difficult to diagnose by that means, for if the diaphysis is broken across above the epiphyseal line the fracture must be classed as dicondylar. Diagnosis depends on the symptoms and physical findings, or if the lower fragment is displaced laterally the roentgenogram will help.

The pathology is that of irregular separation with rounded edges through the soft tissues of the epiphysis. The lower fragment may be displaced forward or backward, and lateral displacement to either side may accompany it. Should the violence be received more directly on the elbow area after the separation has started, an impaction may result, and the lower and softer fragment is severely compressed and deformed. There is a constant hemarthrosis with much swelling, crepitus is usually faint or absent, and the deformity varies with the displacement. If lateral, the forearm seems lengthened and displaced laterally with a change in the carrying angle; if anteroposterior, the forearm also seems lengthened, the arm shortened and the end of the diaphysis may be felt in front or behind, the relative position of bony points at the elbow remaining normal. In all injuries to the elbow in adolescence, where fracture and separation of the olecranon cannot be made out, this fracture should be excluded at once.

Proximity to the joint and interference with arm function demand that these fractures should be carefully reduced as soon as possible and the result checked by skiagram in two directions. Treatment can be given when first seen, as even impacted cases will yield to manipulation. The lower fragment is loosened a little by extension of the forearm in the grasp of the surgeon, the assistant holding the arm. It is then pushed into place with one hand according to the displacement, while the forearm is brought up into complete flexion. The same permanent dressings as are used in elbow fractures are

applied, or the hand may be strapped down over the shoulder on the same side. Immobilization should last two or three weeks and then passive motion cautiously begun, the arm still retained during the interval in flexion.

Manipulation failing, operative treatment is indicated to restore the epiphysis to normal place. Lateral incisions are made (sometimes one side is sufficient), and after the opening of the hematoma under the periosteum, which may remain intact, the line of separation can be seen and a blunt elevator or chisel, aided by external manipulation, will suffice to lift the lower fragment into position. As the line of fracture is soft, reposition holds of its own adherence, and rarely is fixture by a foreign body needed. In fact these cases do not stand foreign material at all well, and it is a question if it is not better to put up with a slight deformity rather than run the risk of infection or secondary operation.

Fractures of epiphyseal separation of the epitrochlea consist of the upper part of the internal epicondyle, not the whole epicondyle. They frequently are a complication of elbow-joint dislocation.

Fracture of the trochlea is rare; Stimson reported a case. Fracture of the external epicondyle is very unusual. If large enough to include the joint, it is best to class it as fracture of external condyle.

Fracture of capitellum is known—Stimson has reported a case. Ashhurst produced one experimentally; the fragment is intra-articular.

In a small percentage these fractures are complicated by splits in the diaphysis. Compound fractures in this region are treated with the general care for that class of injury. The fragments are replaced and wide drainage into copious sterile dressings supplied. No foreign material is put into the bone and the arm is dressed in flexion. Should no infection or a slight skin infection only be present, the wound is dressed without the arm being released from its flexion, and fair results are to be expected. Deep infection, threatened gangrene of the hand on account of circulatory disturbance, or great pain will demand loosening of the dressings and a release of position with surgical provision for proper drainage. Effort is made to save the limb and avoid the toxemia of sepsis, the fact of fracture being made secondary. Deep infection involving the bone or joint will lead to a long disability with resulting restricted use of the elbow. If this is foreseen, it is best to have ankylosis occur with the forearm flexed so that the hand may be of use. After complete subsidence of infection, removal of dead bone and a closing of all sinuses, arthroplasty may be attempted with the use of neighboring tissues or transplanted fascia. Other treatment consists in the freeing of the olecranon and head of the radius with partial resection of them. The bare ends are covered with soft tissues, and by means of early passive motion a pseudarthrosis is developed which leads to a more useful joint.

CHAPTER XVI.

DISLOCATIONS OF THE SHOULDER.

In the remarks preceding the discussion of fracture of the humerus the anatomy of the shoulder-joint has been mentioned, and the abduction mechanism of causing injuries of this joint has been outlined. Before the discussion of dislocation it is necessary that a few points be recalled. The whole head of the humerus does not lie within the glenoid cavity, as the femoral head does in the acetabulum. Only the posterior portion rests against the glenoid surface which looks outward and forward and is less than half the extent in surface of the articular part of the head of the humerus. The bone edge of the glenoid is deepened a little by a rim of cartilage, and the articular capsule and long head of the biceps tendon are attached to it. Attached to the tuberosities of the humerus are the spinati, subscapularis, and other muscles. The ligaments, the muscles, and atmospheric pressure hold the humeral head in place. Important landmarks are the acromion, which can be felt above the humeral head in any patient unless it is broken, and the coracoid, lying just medial to the head. Connecting these two processes is the strong coraco-acromial ligament, which also guards the joint. The head of the humerus constitutes the other landmark, and it is really the most important, as it is the one which moves out of place. Methods of palpating the head and tuberosities are given in the discussion of fracture. The surgeon must familiarize himself with the normal position of these joints and with the "feel" of the head and tuberosities as they roll under the fingers pressed lightly against them when the arm is rotated. The opposite joint is used for comparison. The shoulder-joint possesses a wide range of motion because of the structures described, and because the articulation includes the scapula, which has movement on the trunk. When the humerus is not permitted this freedom of motion, and it is felt to lie in an abnormal position, dislocation is understood.

Frequency and Classification.—At the Cook County Hospital there were 409 dislocations of the shoulder, or 52.8 per cent. of a total of 775 luxations. Stimson's statistics gave 617 shoulder dislocations in a total of 1527. Malgaigne's and Gurlt's collections showed 65 per cent. and 58 per cent. respectively of the shoulder. The luxation is about ten times commoner in men than women, and the largest proportion occurs in the third and fourth decades of life. In the first decade fractures of the clavicle are a more frequent consequence of falls which in adults produce shoulder dislocation. The forms of luxation are: anterior, posterior, downward, and upward. These terms can be

subdivided in accordance with the degree of displacement, and the following simple classification fits all forms.

1. Anterior dislocations.
   (*a*) Subcoracoid complete—common form.
   (*b*) Subcoracoid incomplete (*subluxation*).
   (*c*) Intracoracoid.
   (*d*) Subclavicular.
2. Posterior dislocations.
   (*a*) Subacromial.
   (*b*) Subspinous (scapular spine).
3. Downward dislocations.
   (*a*) Subglenoid.
   (*b*) Erecta.
4. Upward dislocations.
   (*a*) Supraglenoid }
   (*b*) Supracoracoid } Both very rare and accompanied by fracture.

1. ANTERIOR DISLOCATIONS.

Subcoracoid Dislocation.—Subcoracoid dislocation is the common luxation at the shoulder. The head leaves its contact with the glenoid surface and moves forward and inward until it lies beneath the point of the coracoid above. When the head assumes a position farther inward so that more than two-thirds of its mass is found inside the line of the coracoid, the luxation is termed intracoracoid, or, if a still greater displacement inward exists, subclavicular. This differentiation is merely one of degree; it is helpful in clinical description.

The causes are indirect and direct violence and muscular action. The abduction of the arm in the mechanism described for shoulder injuries is the usual cause. The outer surface of the humerus impinges against the acromion or the coraco-acromial ligament, and the head of the bone, levered out of place, escapes through a tear in the capsule at the opposite point, the antero-inferior surface. As the head escapes, the arm usually descends from its abducted position, and the humerus is pulled inward by the attachment of the pectoralis major and latissimus dorsi muscles. It is prevented from dropping downward by the holding of portions of the inelastic capsule on the external lateral aspect of the joint, which become taut and prevent a wide displacement of the head inward. Cotton[1] believes that it is folly to attempt to determine the exact nature of the fulcrum action and thinks that the contracted tendons of the adductor muscles are entitled to consideration as a leverage point. Most authorities agree, however, that the method outlined in abduction injuries causes the majority of subcoracoid dislocations and that all the factors mentioned have an influence.

Direct violence furnished by blows or falls on the shoulder may

[1] Dislocations and Joint Fractures, 1910, p. 155.

cause dislocation by driving the head out of the glenoid. These luxations require great force and are often complicated by fracture of the acromion, if the force comes from above on the glenoid, and of the scapular neck, if the force is directed horizontally. The capsule is generally torn extensively. Eve[1] recorded a case of subcoracoid dislocation by direct violence in which the capsule remained unruptured.

Muscular action causes shoulder dislocation, either by volition or during active use of the arm in reaching, throwing or grasping. The volitional type is really to be classed with habitual dislocation, and the spontaneous dislocations during muscular activity are often attended by some pathological change in the tenseness of the capsule or by joint disturbance. Inward rotation by muscular action undoubtedly causes anterior dislocation and is seen in football players, in wrestlers, and in men making muscular efforts in weight-carrying. This type supports the idea of causative mechanism expressed by Cotton, namely, the leverage action of the muscles alone without bony impingement, because there is no abduction of the arm. It is sufficient to know that all the causes described cause luxation forward at the shoulder. They can be verified on the cadaver, and in traumatic lesions of any sort, especially in fracture and dislocation, it is nearly impossible to state the position of a limb at the exact instant of the injury.

Pathology.—The frequency of shoulder dislocations and complications which lead to an early fatal termination have furnished excellent opportunities for postmortem examinations of the traumatic changes.

The capsule is torn. The tear involves the inner anterior portion, extending for a varying distance along the glenoid rim. It may include a half of the circumference or be very small and incomplete, inasmuch as the heavy fibrous portion is ruptured, and the more elastic synovial surface retains continuity by stretching. The coracohumeral bands extending from the coracoid to the tuberosities are rarely torn and assist in limiting the amount of displacement (Fig. 237). The periosteum is sometimes stripped up. The tuberosities of the humerus are frequently torn out by the pull exerted from the stretched attached muscles. The greater tuberosity is pulled by the spinati and teres minor muscles and is frequently injured (see Fractures of the Greater Tuberosity). The lesser tuberosity is seldom injured by the subscapularis. These muscles may be lacerated or completely torn asunder by the force of the luxation.

The cartilaginous rim of the glenoid may be split off and small fragments of bone loosened which obstruct reduction or favor recurrence. Bony outgrowth from these bone lesions often causes a restriction of motion later. The head of the humerus may be indented or chipped, and in old dislocations the presence of a groove in the bone, probably caused by pressure against the glenoid, has been remarked by several surgeons. When the greater tuberosity is

[1] Med. Chir. Trans., London, 1880, lxiii, 317.

detached, two displacements are possible. The bone fragment may remain partly in position held by some periosteal shreds, or it may be widely retracted and come to lie high up beneath the acromion. After reduction, if the bone fragment does not interfere with replacement, union with the head in an abnormal position may occur, with formation of much callus. This bone growth obstructs shoulder motion, especially abduction. As the tuberosity forms the posterior edge of the groove in which the long head of the biceps passes, the tendon may be exposed and displaced backward on the outer side of the head. By impinging on the roughened bone surface this tendon

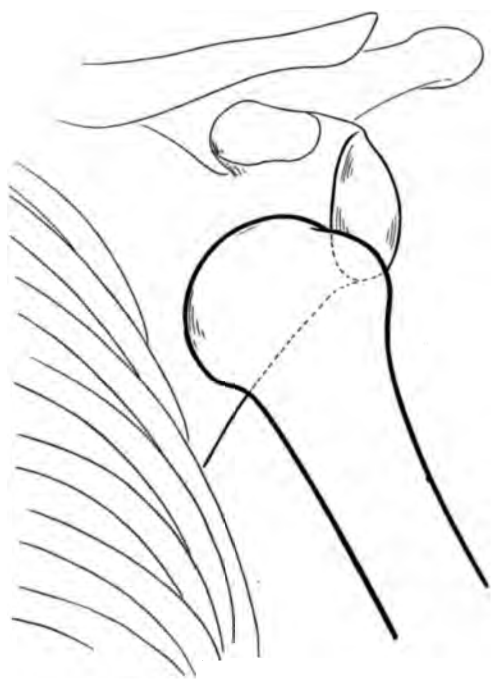


FIG. 237.—Complete subcoracoid dislocation of the humerus. The head out of the glenoid displaced forward and inward.

may seriously obstruct reduction, or it may even be twisted about the neck of the bone when the humerus lies far forward, and make reduction impossible.

The position of the head of the humerus varies in every dislocation. In the forms of subluxation forward it lies just on the glenoid rim; in complete dislocation it lies outside of and against the glenoid or deeper against the scapular neck, the position depending on the muscular attachments and the capsular portions which are untorn. Usually it lies high up against the coracoid, and the secondary position after dislocation may place it well within the coracoid line toward the sternum. The humerus assumes also a position of rotation inward or

outward, according to the character of the causative trauma and the complications of muscle rupture and tuberosity fracture. The usual finding is a slight inward rotation (Fig. 238).

Other important pathological complications concern the injuries of bloodvessels and nerves. These have been given in the general chapter on Pathology of Dislocations, but are so important that the surgeon must bear them in mind when treating every case of shoulder dislocation. Before attempts at reduction are made, examine the arm carefully for any evidence of nerve and bloodvessel damage. These structures are injured by the same force which causes luxation, an

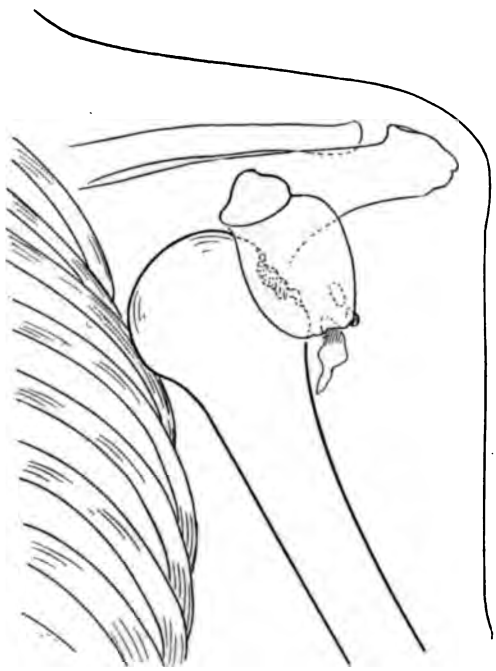


FIG. 238.—Subcoracoid dislocation of the humerus with fracture and displacement of the greater tuberosity. Looked at from behind, the scapular shadow is omitted.

avulsion of the brachial plexus at the spine, for example, or they are injured by the pressure of the displaced head during and after displacement. If the condition of injury, particularly of the nerves, is not noted until *after* reductive attempts, the surgeon comes in for a large share of blame which may not belong to him. All branches of the brachial plexus, or only one branch, may be torn or bruised. The circumflex nerve is also frequently injured, with deltoid paralysis. This injury may be permanent, the muscles supplied may never regain function, and when the shoulder girdle is involved there is loss of tone in the capsule and loss of muscle power about the joint, with a functional weakness.

Many of the serious injuries of the bloodvessels have accompanied manipulative efforts at reduction of long-standing dislocations. There are a few instances of vessel rupture from the luxation alone. A hematoma forms which often pulsates, and if the artery is torn, the radial pulse is obliterated. The pulse may also be lacking because pressure over the axillary artery obstructs it. Körte[1] records an instance of dislocation sustained by a forty-year-old man. The radial pulse was absent but reappeared immediately after reduction. Another interesting case illustrating pressure on the axillary artery by the displaced head was reported by Ericksen.[2] The patient had a wound of the forearm which severed the radial and ulnar arteries. As long as the dislocation remained unreduced there was no hemorrhage from these cut vessels, but when reduction was accomplished they promptly began to bleed. Vincent[3] reported a case in which engorgement of the veins of the arm was caused by the dislocated head pressing on the axillary vein. After reduction the venous edema and hyperesthesia from nerve pressure disappeared. A slight change of position of the arm may permit the blood stream to pass, and pulse will reappear before reduction. The circumflex and subscapular vessels have been torn, as has also the subclavian. Bloodvessel injury with a rapidly forming hematoma calls for radical and immediate surgical interference. Venous rupture offers a better prognosis than arterial, for obvious reasons.

The literature of accidental lesions of the axillary vessels is very extensive, considering the total number of cases on record, and the reader is referred to a few papers which give excellent bibliographies. Makara in the surgical clinic at Budapest from 1867 to 1895 found that there were 138 old luxations treated; 81 of these involved the shoulder, only 2 of which produced axillary vessel injury. The most complete articles are by Körte,[4] Guibé[5] and Andrews.[6] Körte collected 44 cases and reviewed Stimson's collection made in 1885. The mortality was about 70 per cent. More than half the cases were in fresh dislocations, that is, displaced three weeks or less. More than one-third were caused by reductive efforts, and 3 of the cases were directly traced to the trauma of dislocation. The axillary artery was injured 35 times, the artery and vein twice, twice the exact vessel injured could not be located, and 3 cases were cured without operation and no certain diagnosis was made. The final outcome was 31 deaths and 12 cures. Andrews[7] adds 2 more cases which are not mentioned elsewhere in the literature. One was seen by Dr. Ferguson and the other by Dr. A. J. Ochsner in Parke's clinic at Rush College. Both had a fatal termination, Parke's case after ligation of the subclavian. The last extensive review by Guibé counts 78 cases. He found that in 12 cases the accident existed either before reduction or without

[1] Arch. f. klin. Chir., Bd. xxvii, 639.
[2] Handbuch der Chir., i, 374.
[3] Thése de Paris, 1876.
[4] Arch. f. klin. Chir., xxvii, 631; and ibid., lxvi.
[5] Rev. de Chir., 1911, xliv, 581.
[6] Surg., Gynec. and Obst., i, No. 5, p. 385.
[7] Loc. cit.

any attempts at reduction. In 57 cases the bloodvessel lesion was discovered after attempts at reduction and complete reduction performed either immediately after dislocation or a lapse of some time. If the cases are considered as to time after dislocation, 31 vascular lesions occurred from reduction within three weeks or less, 15 after a period of three weeks to two months, and 10 in cases which had remained luxated two months to a year. One is likely to consider the vascular lesions more frequent after fresh dislocation if the ratio of 31 to 25 is taken from these figures, but this ratio is absurd when one considers the great preponderance of fresh dislocations over old ones. The collateral arteries are also wounded. Joessel[1] made a postmortem examination of a recent shoulder dislocation and found the circumflex nerve and artery much stretched but not quite torn. Among 13 cases of rupture of the collateral arteries in Guibé's collection only 1 was in an old dislocation. In 2 no definite time information was given, and 10 were in recent dislocations; 11 cases of injury of the axillary branches were noted; 9 were specified; 5 involved the posterior circumflex, 3 the inferior scapular, and 1 the long thoracic.

The total lesions are divided as follows: 65 of the axillary artery, 6 of the axillary vein alone, 6 of both vein and artery.

To these should be added von Haffner's[2] case, in which a man fell, dislocated the shoulder and obtained a spontaneous reduction and fatal rupture of the artery, and the 2 cases previously cited by Andrews.

Open dislocation is extremely rare. The accompanying injuries and shock are often fatal. Complications of open dislocation consist in nerve and bloodvessel injury, immediate thoracic injury involving ribs and lung, and the possibility of infection and ankylosis. The dislocated head must be cleansed and reduced, with drainage from the joint for thirty-six hours. The soft parts are not stitched at all, but the wound is left to close with every facility for drainage outward, and no retention of discharges under pressure.

Symptoms and Diagnosis.—In the average case the injured arm is held supported by the opposite hand. The elbow stands out from the body and cannot be pressed back on account of rigidity and pain, and the hand cannot be placed on the opposite shoulder. This failure is known as Duga's test. The patient leans toward the affected side. Examination reveals that the anterior axillary fold is lower on the dislocated side, the long axis of the humerus points more obliquely inward than on the opposite side, and the outer aspect of the shoulder is flattened. The deltoid seems stretched down tightly over the acromion, and its fibers may show fibrillary contractions (Fig. 239). Palpation determines the abnormal position of the head anterior to and on a level with the glenoid and not in the axilla. There is a corresponding swelling over the head which is recognized by slight rotatory manipulation, the motion being felt by the fingers as the bone rolls

[1] Deut. Zeitschr. f. Chir., Bd. xiii.
[2] St. Petersburger Med. Wchnschr., 1911, No. 44, p. 464.

beneath. The depression beneath the acromion can be palpated; the glenoid is seldom felt. All active motions of the arm are lost, and passive motion is painful and restricted (Fig. 240).

FIG. 239.—Subcoracoid dislocation of the humerus. Note the flattened shoulder, lowered axillary fold and oblique axis of the humerus.

FIG. 240.—Subcoracoid dislocation of the humerus. Note the apparent lengthening of the arm.

Measurement of the arm's length shows no shortening or a slight lengthening compared to the opposite side. There is always an *apparent* lengthening.

Confusion in diagnosis can exist only in cases of subluxation and fractures of the anatomical and surgical neck of the humerus (which see). In the fractures there is generally crepitus and shortening and no evidence of anterior luxated position of the head. Dislocation and fracture together are very difficult to determine. It is important to be sure of the presence of fracture complicating luxation, and every diagnostic means must be used to establish the fact in a given case. Measurements, crepitus, deformity, and roentgenogram make the diagnosis positive.

Treatment.—Difficulty in reduction of shoulder dislocations is explained by a complete understanding of the varying pathology of the lesion. In and about the joint itself the interposition of the torn capsule, its tight closure about the neck of the bone, a split-off rim of cartilage or bone from the glenoid may interfere. When the arm drops down, and the head of the humerus is pulled tightly against the scapula by the intact outer and posterior portion of the capsule, relaxation may be obtained by the attendant's pushing the elbow upward before attempting abduction. If this posterior capsular portion is torn completely, and the shreds fall over the glenoid surface, manipulations of the arm do not disturb them, because their attachment is severed, and it may be impossible to work them out of the way. Anterior dislocation always occurs at the expense of the external rotator muscles, which are put on a stretch. Rarely the muscle itself is torn, but more frequently, as in all dislocations, the bony insertion tends to pull out, and the line of cleavage involves the humerus, particularly the greater tuberosity, as we have seen. Its individual facets may be detached, the upper, which holds the supraspinatus, or the posterior, which holds the infraspinatus and teres minor.[1] The bone fragments may interfere with reduction, but have not done so in my experience unless the luxation is old and a large fragment has retracted well up under the acromion. Frequently the fractured tuberosity is discovered sometime *after* reduction of shoulder luxation, when function does not return, especially the movements of abduction. The biceps tendon, liberated by tuberosity fracture, may block reduction. The pull of the unopposed or spastically contracted internal rotators of the arm must also be considered as obstacles. Both actual pain and fear of pain incite these muscles to powerful contractions to hold the bone steadily in its new position. External rotation and abduction of the arm overcome most of these obstacles, but in some instances these movements will not be permitted by the patient, even when his confidence has been gained and his attention is distracted elsewhere. In these cases, in order to permit manipulative efforts and to hasten the reduction, one may give a general anesthetic. Gas is efficient

[1] Telford, Med. Chron. Manchester, lx, 218.

especially with women. For some men surgical anesthesia with ether is needed, but in most of them, even alcoholics, the ether rausch gives sufficient relaxation. An anesthetic of the degree needed has little danger and is preferred to painful and tiresome attempts at traction and manipulation. But even with anesthesia shoulder luxations of some standing may resist all reasonable efforts by manipulation and traction, for the pathological reasons given. In such instances undue force must not be used, and the case must be put in the class for open reduction. Each case is a law unto itself and must be judged in the light of the surgeon's experienced examination. After several weeks or even a couple of months the experienced hand may reduce a dislocation which had previously resisted all manipulative efforts.

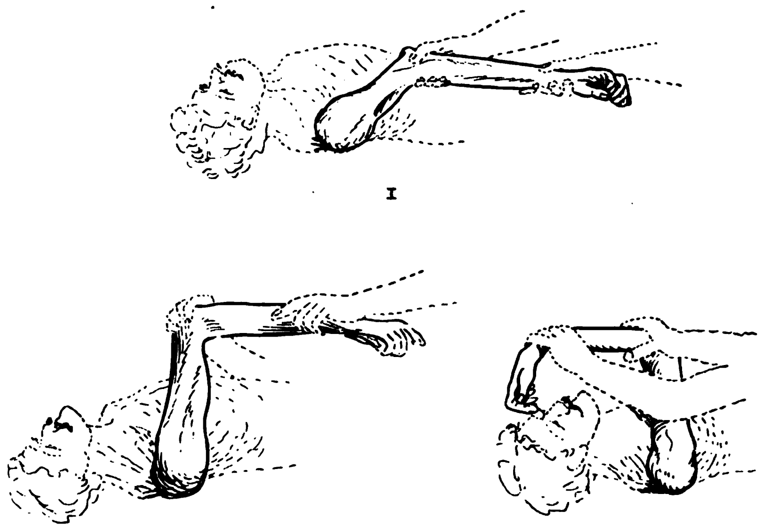


FIG. 241.—Kocher's method of reduction of anterior shoulder dislocations. The steps performed in the numerical order of the figures. See text.

Methods of Reduction.—A. *Manipulation.*—This method is that described by Kocher[1] and consists of manipulation with rotation. The untorn and tense portions of the capsule which are stretched over the glenoid are relaxed by external rotation of the arm and by elevation of the elbow. The tear in the capsule widens, and when the arm is fully rotated outward and elevated the head is slipped over the glenoid rim and dropped into the glenoid cavity by subsequent internal rotation of the arm. The muscular resistance of the subscapularis and pectoralis is overcome by steady outward rotation in the first stage of the reduction. When the surgeon masters the method, appreciates its gentleness and efficiency, and uses it systematically, he will find very few uncomplicated cases which are irreducible.

[1] Berl. klin. Wchnschr., 1870, No. 9.

Kocher's method in detail is as follows: The patient lies on a table; the surgeon stands on the injured side (Fig. 241). One hand grasps the patient's elbow firmly, while the other holds the wrist with the forearm flexed at a right angle. Slowly the arm is rotated outward by the surgeon turning the forearm outward. At the same time the elbow is pushed upward slightly. If there is obstruction to rotation and the head of the humerus does not turn outward, the efforts must be slowly repeated. This manipulation stretches the subscapular and pectoral muscles and opens the tear in the capsule. The head now rides up on to the glenoid rim and may slip in quickly.

After obtaining rotation the surgeon takes the second step, which consists in raising the elbow and arm up across the patient's chest. I try to keep in mind that an attempt is being made to approximate the point of the elbow to the nipple on the same side. This action further rotates the head outward and uses the untorn posterior portion of the ligament as a fulcrum for the levering of the head into the glenoid.

The third step consists in the surgeon rotating the arm inward by holding the elbow in its elevated position and sweeping the forearm across the patient's face and letting the arm come to the side in a natural position. The important point in the manipulation which is often slighted is the elevation of the elbow as high as possible at the time of maximum rotation outward.

B. *Traction.*—(1) *Downward Traction with Leverage.*—Downward traction with leverage is also a useful method. The dislocated arm, which lies in abduction, is pulled downward in the direction of its long axis and abduction is made during the traction, while an outward pull is exerted on the arm in the axilla by a broad piece of bandage or an assistant's fist used as a fulcrum.

(2) *Traction with the Heel in the Axilla.*—Traction with the heel in the axilla is a method like the preceding one in principle. With the patient lying on his back, the surgeon grasps the wrist of the dislocated arm and makes traction at a right angle, pressing his stockinged foot in the axilla for counter-traction and for use as a fulcrum. The arm is slowly adducted during the pull. This method is dangerous, inasmuch as great force can be exerted by the weight and swing inward of the surgeon's body during the traction. The surgical neck of the humerus may be broken. I have seen that accident occur. Vessels and nerves may be torn or avulsed by the direct traction or the pressure of the heel in the axilla. The method does not take the local pathological conditions into consideration, and there is no rotation outward to open the capsule. Reductions can be made in this way, but it is more painful and dangerous than Kocher's method and has no compensating advantage over it. When reduction fails, the surgeon is likely to exert too much force and cause injury, so that the method should not be used as a routine, but only in cases of failure by manipulation.

(3) *Direct Reduction.*—Direct reduction is useful when the capsular tear is extensive or there is merely a subluxation. The arm is held in slight abduction, the patient standing or sitting, and the elbow is pressed up. The surgeon makes direct pressure on the head of the bone to force it back into the glenoid. A hand may be slipped into the axilla for direct pull on the upper end of the humerus outward and backward, while the other hand steadies the scapula.

(4) *Downward and Outward Traction.*—Downward and outward traction can be employed in two ways. The first consists in the fixing of the patient in bed by counter-extension applied by a broad band around the chest. The dislocated arm is grasped, pulled outward with or without the heel in the axilla, and at the same time rotated outward. The head of the humerus is watched for the change of position denoting its approach toward the glenoid, and when it has descended may be pressed down into the cavity by an assistant, while the surgeon brings the arm to the side. Instead of placing the heel in the axilla the surgeon may place the patient on the floor and use both feet, one against the chest and the other against the acromion, drawing the arm directly outward. Stimson has modified this method by using a canvas cot with a sixteen-inch hole at a point where a man's shoulder would lie. The patient lies on the cot, and to his luxated arm projecting through the hole toward the floor is hung from the wrist a weight of about ten pounds. Reduction takes place quietly and painlessly in a few minutes.

(5) *Upward Traction.*—Upward traction is seldom used in anterior dislocations, its greatest use being in subglenoid or erect dislocation. Direct pull upward is made by the surgeon grasping the wrist, counter pressure being exerted against the acromion by the heel or pull of an assistant, and the arm, gradually swung outward and let down, is lifted into normal position. The method really corresponds to outward traction, because the relation of the arm and scapula do not change after abduction and elevation to a right angle are obtained. Further movements upward are only by rotation of the scapula on the chest. There are many modifications of this plan, the easiest of application being that of Malgaigne, who fastened a band about the patient's wrist, had him stand near a door, and by passing the end of the band over the door top made traction upward on the arm until the dislocation was reduced.

Operative Treatment.—Operative treatment is seldom necessary in recent cases, except in the few irreducible ones or those complicated by fracture and injury of other structures. It is discussed under the subject of Old Dislocations.

Treatment after Reduction.—After reduction the joint must be held in a position of rest until its structures are healed and the surrounding muscles regain tone. This requires two to three weeks' immobilization. For the arm to be held in a position which favors healing of a tear in the anterior portion of the capsule the humerus must be rotated inward and the head should point outward. This position

is secured by a bandage or dressing which holds the elbow in against the front of the chest and the forearm rotated in to permit the hand to lie either on the opposite shoulder or across the upper part of the opposite side of the chest. The dressing may consist of a broad piece of adhesive plaster applied like the second part of the Sayre's dressing for fracture of the clavicle, or it may be a few turns of plaster of Paris over a cotton bandage. Cotton[1] uses a band of adhesive passed around the arm and across the chest in front to hold the arm steadily in and a separate muslin sling to suspend the forearm from the neck. Danielsen[2] advises a position in which the arm is placed alongside the cheek and the forearm is flexed over the head, the whole encased in plaster of Paris to promote a maximum relaxation of the muscles about the joint and an approximation of the torn capsule. Braatz[3] admits the physiological correctness of the position, but believes that it is irksome to the patient and advises that the same position can be secured by the shoulder being pressed well forward and fixed firmly by a strap of adhesive which extends on the chest wall in front.

After two or three weeks the bandages are removed, and the arm is massaged daily, the forearm hanging in a sling for ten days longer. Active and passive movements are controlled by the pain they cause, no painful motion being permitted. The patient is warned to avoid movements which rotate the arm outward or abduct it, such as those involved in putting on coats or shirts.

The results vary with the individual injured and probably also with the extent of the pathology. The ecchymoses about the joint and down the arm may be weeks in absorbing. Swelling is not great, and the motion of the shoulder-joint gradually returns to normal in most cases. There is tenderness in the joint for some time, although I have frequently seen laboring men who had suffered a traumatic shoulder dislocation able to use their arms in any manner in three weeks with no complaint of pain or weakness. Young adults usually recover quickly. In older people the immobilization alone may lead to stiffness and restriction of motion. Those with a tendency to gout or osteo-arthritis are likely to find restricted shoulder motion after two weeks' immobilization. There may also be lime deposits made in the periarthritic tissues.[4] Recurrences of uncomplicated dislocation are rare, especially if they are accorded proper reduction and after-treatment. (See Subluxation and Recurrent Dislocations.)

The complicated cases do not fare well. We have seen that the mortality following vascular lesion is very high in spite of all treatment. The lesions of nerves vary in result according to their character. Contusion and stretching with no loss of neurone continuity give a favorable prognosis, avulsion of a single nerve or trunk of the plexus

[1] Joint Fractures and Dislocations, p. 168.
[2] Zentralbl. f. Chir., Leipzig, 1914, xli, No. 41.
[3] Ibid., p. 1673.
[4] Wrede, Arch. f. klin. Chir., Berlin, xcix, No. 1.

offers no hope, in spite of massage and electricity, until operation and plastic repair is attempted. Tearing out of the tuberosities, laceration of the spinati and subscapular muscles or their insertions, lead to permanent restrictions of shoulder motions. Abduction becomes almost *nil* when the tuberosities are loose, and the joint may lock from the presence of a loose fragment. Dislocation complicated by fracture of the humerus at the neck may give a fair result even when unreduced. The question of old unreduced dislocations is considered separately.

Subluxations.—Subluxations forward are not common, but they are puzzling on account of the physical findings and the lack of functional use of the joint. A primary uncomplicated traumatic subluxa-

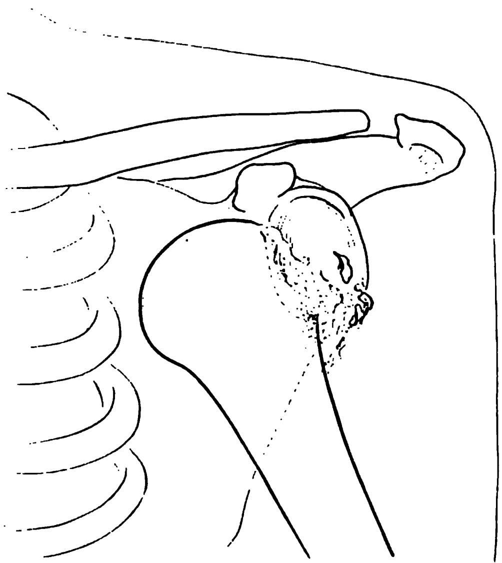


FIG. 242.—Old subluxation forward of the humerus. The head lies on the anterior lip of the glenoid, the greater tuberosity has been avulsed and there is callus formation. Note the flattened shoulder from long disuse of the deltoid.

tion is not a definitely accepted clinical entity, but I believe it does occur. In the last eighteen months I have seen two cases which would come under this classification (see Fig. 242). Malgaigne[1] referred to incomplete anterior dislocation. Stimson and Hamilton believe it occurs. Subdeltoid bursitis or dislocated long head of the biceps tendon may simulate it. Primary cases are probably caused by direct violence on the shoulder, and some of the subluxations undoubtedly result from incomplete reductions of primary subcoracoid dislocations. The head seems to bulge and to rest slightly forward compared to the opposite shoulder. There may be some flattening

[1] Traité des Fract. et des Luxations, Paris, 1855.

on the posterior aspect of the joint, and motions are restricted and may be painful. The deltoid contour usually shows no changes.

The change in the relation of the humeral head to the articulating glenoid surface consists in a slight advancement of the position of the head, so that it probably rests on the glenoid rim. The capsule may be torn anteriorly or simply stretched. Why the head should come to rest in this anterior position is a difficult matter to determine. Some of the reported cases have had accompanying pathology which might account for the subluxation. South reported a case verified by autopsy. There was a small capsular tear, also a fracture of the coracoid, acromion and clavicle, and the head rested on the anterior glenoid margin. Other instances have been recorded by Hargrave, Petit, Dupuytren and Astley Cooper. Cooper had 2 cases and dissected a third in which he found the tendon of the long head of the biceps ruptured and the humeral head lying below the coracoid, having formed a new articular surface on the neck of the scapula. One case in which the periosteum on the anterior surface of the neck was stripped up was reported by Broca and Hartmann.[1] The capsule was intact but the anterior half of the interarticular cartilage was torn loose. Russ[2] reported 7 cases of subluxation seen in a period of from two days to six months after accident. Vale[3] reported a traumatic subluxation accompanied by subluxation of the acromial end of the clavicle. Since then Miriel[4] has added 5 cases and Brickner[5] 3 cases. Brickner found that abduction of the shoulder was limited and painful, but that inward rotation was normal, so that the patient could put the hand up behind the back. When the arm was abducted to a horizontal position, the prominence of the humeral head disappeared, and the patient could then continue the abduction unaided. After the arm was lowered the deformity and pain reappeared. Differential diagnosis must exclude tumor or osteomyelitis of the upper end of the humerus, dislocation of the biceps tendon, and various arthritides.

Treatment.—Treatment consists in complete reduction by Kocher's method or by a holding of the arm in abduction for two weeks (Brickner advises 135 degrees). I operated on 1 case and found no dislocated biceps tendon, but a slight mashing and overgrouth of the glenoid rim. This was removed, and the capsule was stitched on the anterior surface, but the reposition was not perfect, as shown in stereoscopic roentgenogram.

Intracoracoid and Subclavicular Dislocation.—As previously mentioned, this form of shoulder luxation implies that the head of the humerus lies *farther* inside of the coracoid line than the subcoracoid type. The differentiation is purely artificial, and until the head of the bone leaves the coracoid area altogether and lies under the clavicle,

[1] Bull. Soc. Anat. de Paris, 1890, lxv, 312.
[2] Surg., Gynec. and Obst., 1909, viii.
[3] Washington Med. Ann., 1908, vii, 5.
[4] Gaz. des Hôp, Paris, 1912, lxxxv, 1307.
[5] Am. Jour. Surg., 1915, xxix, 50.

the luxation might still be termed subcoracoid. Considering the wider displacement, one expects *more pathology* than in a subcoracoid about the luxated head. The capsule is more widely torn. There is more swelling and a greater violence has acted. This displacement results also in tearing off of the bony surfaces of the tuberosities, laceration of the subscapularis muscle, and greater pressure on the contents of the axilla. The arm is in a position of greater abduction, the head of the humerus lies higher and farther in toward the median line immediately beneath or even behind the clavicle. Beneath the acromion there is a more prominent hollow and the arm is shortened. When the arm is abducted, the shoulder sticks and the movements obtained include the scapula. In some rare instances the arm remains abducted after the luxation, and the head is driven forward and inward so that the arm stands out widely.

Treatment.—Treatment of this type of dislocation is reduction by the different means used for subcoracoid luxation. If the displacement is distinctly subclavicular and the head lies far inward and is rigidly bound in slight inward rotation, it is wise to make lateral and downward traction on the arm in order to pull the head out until it comes to rest under the coracoid. This traction may be continued until reduction occurs, especially if the ligaments have been widely torn. After a subcoracoid position is reached and the ligaments and capsule appear not to be torn more than in an ordinary case, any of the maneuvers of reduction will effect a replacement.

2. POSTERIOR DISLOCATIONS.

These are classified as subacromial and subspinous, depending on the position the head assumes in relation to the acromion process and spine of the scapula. As in the case of the anterior dislocations, the division is quite arbitrary, except in the rare instances of complete subspinous displacement. Posterior traumatic dislocations are uncommon; a few of them occur in infants at time of delivery, or are congenital in character. Hitzrot[1] recorded a case in an eight-year-old girl.

The causes are usually falls on the elbow with the arm adducted, muscular action, or direct violence from a blow against the front of the shoulder. The mechanism is first internal rotation of the arm and humeral head, then tearing of the posterior portion of the capsule, and continuation of the pressure, forcing the bone head out posteriorly. Many cases occur during epileptic fits from muscular contraction or falls. Malgaigne collected over 30 cases in 1855, and there have been about 20 more added to the literature since that time. Some of the cases have permitted careful examination, as the patients suffered other and fatal injuries.

[1] Ann. of Surg., lv, 622.

Pathology.—The pathology involves the capsular ligament, which has been rather widely torn in all cases examined. The greater tuberosity of the humerus has frequently been avulsed, remaining near its normal position. The subscapularis muscle and lesser tuberosity have been found torn off, and the long head of the biceps may be displaced from its groove and come to lie on the axillary side of the bone, as in Hitzrot's case. The spinati muscles are usually unharmed. Fracture of the humeral neck may be a complication.

Symptoms.—The arm has generally been found rotated inward and adducted so that the elbow presses against the side of the chest wall. Arm movements are painful and restricted. The length of the arm does not vary enough to be of any value for diagnosis. Examination of the shoulder shows swelling, which may mask the position of the head. The front of the joint seems flattened, the acromion is prominent, and pressure over the anterior surface of the shoulder fails to feel the round head of the humerus. On the back of the joint there is swelling, and the head can be felt to rotate with the shaft. Subacromial dislocations are likely to be overlooked, much as subluxations forward, and both shoulders must be compared. The long axis of the humerus may be directed backward enough to be of aid in diagnosis. In the subspinous variety, the head has moved well backward and inward and has dropped away from the acromion to such an extent that a finger may be pressed in between them. The joint in front is strikingly empty, and the arm may be in abduction and internal rotation.

Prognosis.—The prognosis of the subacromial type is good, as reduction is easy. The cases which are overlooked on account of swelling may be difficult to replace, and function can be greatly limited if reduction is not prompt. Muscle and capsular lesions heal readily. The diagnosis must consider bursitis and sprains or contusions about the shoulder-joint. The fulness of the shoulder posteriorly and the disappearance of such fulness after reduction efforts confirms diagnosis. Roentgenograms of both shoulders in corresponding positions will aid materially.

Treatment.—Treatment is accomplished by traction on the arm down and outward, accompanied by slight rotary motions to open the capsular tear. Direct pressure on the head by the thumbs of an assistant may push the head forward into the glenoid. After the arm is pulled downward it can be adducted and rotated inward for the relaxation of the intact anterior position of the capsule and the attached muscles, the head being levered thus gently back into the glenoid. Recurrence after simple traumatic posterior dislocation should not be more frequent than after anterior dislocation. If there is complicating pathology involving fractures of the tuberosity or glenoid rim and muscle laceration, reduction may be incomplete, and if function is interfered with, open operation will be indicated. One must consider the possibility of permanent cure very carefully before operating on epileptic or paralytic cases who lack muscle tone.

3. DOWNWARD DISLOCATIONS.

Downward dislocations are divided into subglenoid and luxatio erecta.

Subglenoid Dislocations.—Subglenoid dislocations comprise those in which the head of the humerus has been displaced downward on the tendon of the long head of the biceps muscle or has assumed a position beneath the glenoid rim and lies on the under surface of the scapular neck. This position, considered as a permanent displacement, is uncommon, but it doubtless occurs frequently in the course of what finally becomes a subcoracoid dislocation.

Cause.—The cause is hyperabduction of the shoulder by the individual raising his arm forcibly, as in raising a person by a violent jerk on the arm, or by his falling into a narrow space with the arm extended. Pitching falls on the extended arm offer the same mechanism. The capsular tear is in the lower border between the subscapular insertion in the lesser tuberosity and the biceps head. The subscapular muscle is generally torn. In Leroy's case[1] the capsule was torn on the lower internal border along the edge of the glenoid and was also separated at the upper part, including the insertion of the spinati muscles. The head of the humerus rested on the axillary border of the scapula and was so rotated that the greater tuberosity rested against the anterior border of the neck of the scapula. The subscapular artery and the circumflex artery and nerve may be injured. In all the cases I have seen there has been a complicating fracture of the greater tuberosity.

Symptoms and Diagnosis.—The arm is more abducted and appears shorter than in subcoracoid dislocation. The difference in length of the two arms may be but little by mensuration. The long axis of the humerus prolonged passes through the upper part of the chest and does not point up into the neck so acutely. The humeral head lies in continuity with the shaft and can be felt and seen bulging out the axilla. There is flattening of the deltoid area and a palpable hiatus exists between the acromion and the head. As in types of forward dislocation the differentiation between subglenoid and subcoracoid luxations may be merely a matter of slight difference in position of the head. In the true subglenoid type the head lies in the axilla behind the border of the pectoralis major and not under it.

Treatment.—Treatment is traction outward and slightly upward, with some external rotation to open the capsular tear. This action lifts the head on to the glenoid, and by the arm being swung it can be levered into position. Direct pressure upward on the head during traction may push it quickly into place. Any of the methods for subcoracoid dislocation may be used, especially if in the manipulation the head rides farther forward and tends to assume a subcoracoid displacement. Fracture of the tuberosity must be excluded after reduction, and a roentgenogram should be made.

[1] Bull. de la Soc. Anat., 1844, p. 102.

Luxatio Erecta.—This is an unusual and excessive type of subglenoid dislocation, caused by forcible abduction of the arm and possibly by additional force which pushes the head downward after it is pried out of the shoulder cavity. The arm is completely elevated, the forearm rests across the head and there is pain and rigidity on all attempts to lower it. There is great capsular damage, with associated muscle tears. Fracture of the tuberosities, injury of the axillary vessels and nerves, and the circumflex nerve and artery are expected. Diagnosis is not difficult. The arm is held rigidly up, the head of the bone can be felt in the axilla, and there is no fracture of the humerus. The acromion may be broken off from pressure of the humerus as the displacement occurs. I have seen one case in which the humerus was broken at the surgical neck after the head was in a position of extreme subglenoid dislocation; the arm fell to the side, leaving the head out of the joint turned upside down. There was shortening of the arm and much pressure pain. Diagnosis was made from the roentgenogram.

Reduction is made by traction upward to pull the head back into the glenoid *via* the tear in the capsule on the lower border. Direct pressure upward on the head is of assistance. The arm is then lowered to the side by adduction.

4. UPWARD DISLOCATIONS.

Upward dislocation, when the head lies in a supraglenoid position, is extremely rare. Stimson[1] has collected 14 cases starting with the first case reported by Laugier[2] in 1834. The recent literature of dislocations has been barren of this type, and on account of its rarity and the disputed true character of most of the reported instances, only the essential points will be discussed. The cause is probably extreme violence directed against the arm in an upward and forward direction, possibly applied at the elbow with the forearm in flexion.

The humerus is displaced upward and forward. Capsular lesion must occur on the upper margin, and if the displacement is great the whole capsule and the periosteum about the neck may be stripped off. Fracture of the acromion, coracoid, greater and lesser humeral tuberosities, and even of the clavicle may be complications. The long head of the biceps tendon is either torn from its insertion at the top of the glenoid rim or it remains adherent, and the head rides forward and upward, leaving the tendon on its inner surface below. Experiments on the cadaver show that outward rotation of the arm accompanied by an upward driving force can produce the dislocation. The deltoid fibers may be separated, the head forcing its way through them. Muscles attached to the tuberosities may be lacerated or torn loose from the bone.

[1] Fractures and Dislocations, 7th edit., p. 651.
[2] Arch. Gen. de. Med., 1834, x, 35.

Symptoms and Diagnosis.—The head of the bone is plainly seen riding upward and may project an inch above the acromion. Rotatory shaft movements cause this head to move, and the arm is shortened. Posteriorly the shoulder appears flattened, and the deltoid fibers may be relaxed, if the bone has punctured through them. The coracoid and acromion cannot be satisfactorily palpated. Shoulder movements are restricted and painful, and the arm lies close to the side.

Treatment.—Practically all the cases reported have been old cases in which traction failed to effect reduction. In recent cases, one of as long standing as thirty days, traction downward aided by direct pressure on the head has made reduction. Some of the long-standing cases were given no treatment. In the hands of modern surgeons open operation would undoubtedly be performed to free the head of the bone, hollow out the glenoid and cover its surface with a fat or fascial flap for arthroplastic purposes. A simpler operation would consist in excision of the head and a covering of the neck with a tissue flap to form a false joint at the site of the old glenoid cavity. The deformity alone would hardly constitute an indication for open operation, if the function were at all satisfactory. A painful and stiffened arm bound close to the side would surely be mobilized in the present era of joint surgery.

Habitual and Recurrent Dislocations.—Recurrent shoulder dislocations which become habitual are not common. They are practically all of the anterior type. They occur frequently in epileptics who are subject to falls in convulsions and have suffered one or more traumatic dislocations.

Causes.—The causes are assigned to three different sources, or a combination of them, by most authors. In 1886 Löbker called attention to anatomical defects in the shape of the head of the humerus which were like compression grooves, and which were supposed to permit the head to slide easily over the glenoid ring. The bone defect in the humerus by groove, or the tearing of the tuberosities and bone avulsion of the glenoid rim, comprise one class of causes. Two other conditions favoring recurrence are supposed to be laxity or incomplete healing of the capsule, and tearing or atrophy of those muscles which act to hold the humerus up against the glenoid and so tend to prevent dislocation (external rotators).

(1) *Bone Defects.*—Löbker's specimen showed a deep groove in the head in a part of its circumference which rested next to the glenoid. The cartilage over this depression was smooth and showed no injury, nor was there evidence of compression fracture of the bone at that site.

Grègoire[1] made an anatomical study of the head of the humerus in recurrent dislocation and stated that he considered the groove or notch present in the humeral head was the main cause of habitual

[1] Rev. d'Orthop., January, 1913.

dislocation and that the deformity was a congenital one antedating the first dislocation. Laxity or attenuation of the capsule practically always accompanies this bone deformity. He attempted to prove his assertion by studying the internal arrangement of the trabeculæ in the head. In recurring dislocations, he found a regular trabecular arrangement as in the normal head, contrasting with the irregular distortion of trabeculæ in old unreduced dislocations, which also present this type of groove or notch. When the inner edge of the glenoid has been chipped or torn away, we may expect dislocation to occur more easily, but this defect has less importance in the causation of habitual dislocation than it has in subluxation. If the notch in the bone and a weakened capsule are the main causes, the recurrent mechanism is explained on the basis of elevation of the abducted arm with external rotation. The capsule yields in front, the notch locks over the anterior border of the glenoid rim, and a slight trauma is sufficient to force the dislocation on to completion.

(2) *Laxity.*—Laxity and incomplete healing of the fibrous portion of the joint capsule, with or without head abnormalities, is given as a principal cause. Thomas[1] is of the opinion that recurrent luxation is exclusively caused by capsule laxity and that the condition is a *hernia* of the joint, a thinning of the fibrous portion, permitting a bulging weakness of the synovial portion like a sac.

(3) *Atrophy or Tearing of the External Rotators.*—Atrophy or tearing of the external rotators of the shoulder and the shoulder-girdle muscles is also considered a main cause. The most recent champion of this factor is Selig,[2] who considers it of superior importance over bone deformity, glenoid injury, and looseness of the capsule.

Probably no one pathological group of conditions can be made to cover all cases. The observations of all operators who have reported cases must be put together, and the results they have obtained must be sifted until conclusion can be reached as to the cause of most of the cases and the procedure which will effect cure in the majority. An extensive capsule laceration which has never been properly healed, a laxity of the whole capsule of long standing, rupture or atrophy of the external rotators of the humerus, and fracture of the glenoid rim or other bone defects previously enumerated, may be present in any combination.

Treatment.—The simplest treatment of habitual dislocation consists in the avoiding of recurrence. That means avoidance of abduction and elevation of the arm, for some cases slip out of place so easily that the act of putting on a coat or raising the hand to the head is sufficient to produce luxation. Recurrence can be warded off by the patient's wearing a stiff shoulder cap which inhibits abduction and elevation, or by wearing about the wrist a strap which is fastened to the waist affording enough play for some uses, but prohibiting the dangerous positions. Reduction after habitual dislocation is

[1] Surg., Gynec. and Obst., 1914, xviii, 107; Am. Jour. Med. Sci., February, 1909.
[2] Deutsch. Ztschr. f. Chir., Leipzig, 1915, cxxxii, 581.

generally easy to perform. Sometimes the patient can do it himself or can direct others with little pain to himself. A few persons can cause both a dislocation and its reduction by muscular action, and the act can be repeated any number of times. Usually the intervals between luxation are variable and dependent on thoughtless movements or slight accidental trauma. Rarely the fear of pain of reduction on the part of patients necessitates the use of anesthesia.

Operative treatment offers hope of much improvement and probable cure, and the condition cannot be made worse. Operations repair the pathology as it is found or simply make an ordinary capsular replacement with or without strengthening it. Hildebrand reported 25 operative cases[1] and Perthes 4.[2] In their operations they deepened the glenoid cavity when it was found to be shallow, packed pouches in the capsule with gauze and reattached the external rotators to the tuberosity, or tucked the capsule as indicated.

Thomas[3] is a firm advocate of capsule plication (capsulorrhaphy), basing his opinion on the fact that bony contact between the humerus and the glenoid cavity is maintained at all times in a normal shoulder in any position. His report covers eighteen shoulders operated on in sixteen patients and after his preliminary work on the cadaver he now advises the axillary operation. He performed twelve out of eighteen operations by an axillary incision anterior to the large vessels and nerves. Two successful cases done by this approach were reported by Telford.[4] Thomas now offers the posterior axillary operation as a simpler procedure, the time for completing it being but from twenty to thirty minutes. The arm is held out at right angles to the body, and a four-inch incision posterior to the axillary vessels is made over the head of the humerus. The latissimus dorsi tendon is the guide at the bottom of the wound. This tendon is retracted downward, and the subscapular muscle is pulled upward and freed from the capsule which lies just beneath. The circumflex nerve and artery are identified and isolated. Palpation of the glenoid and head of the humerus shows the extent of the capsule, which is then cut open from the top to the bottom midway between the glenoid and humeral attachments. If necessary, the head of the bone can be inspected or loose bone fragments can be removed. The head is placed in the glenoid, and the capsule is overlapped and sutured without too much tension. Drainage is instituted by means of a rubber tube, which is removed the next day. The skin is sutured and the arm is bandaged to the side with an aseptic axillary pad. This becomes saturated and needs daily renewal. After three weeks a non-epileptic patient begins movements upward anteriorly, which he increases until after five weeks he is urged to climb a hanging rope or hang from a horizontal bar, and the shoulder movements rapidly become normal. Epileptic patients are kept quiet at least four weeks before motion is permitted. Thomas states the following advantages of the posterior axillary open-

[1] Arch. f. klin. Chir., lxvi, 360.
[2] Deutsch. Ztschr. f. Chir., lxxxv, 199.
[3] Loc. cit.
[4] Lancet, London, August 3, 1912.

ing over the anterior: It makes a smaller wound, the large axillary vessels and nerves do not come into view, and the anterior circumflex vessels are not injured as they are in the anterior operation. Capsular access is easier and more rapid. Time of operation is shorter, normal motion returns more quickly, and there is less buried suture material.

The results of capsulorrhaphy are very encouraging. Of Thomas's 18 operations, 16 were successful, 1 partially successful, and 1 a failure. The earlier this operation is performed, the better the chance of cure. Non-epileptics offer a better prognosis than epileptics, and the failures in late cases are probably caused by the groove defects in the head of the humerus or the glenoid and the great laxity of tissues afforded by the repeated luxations.

Other methods to strengthen the weakened capsule in addition to capsulorrhaphy have been used. Wernsdorff[1] advised open operation on all habitual shoulder dislocations, but, because he believed capsular plication alone was insufficient, he took the short head of the biceps and fastened it to the lesser tuberosity to strengthen the active restraining apparatus in front of the joint. Openshaw reported 3 cases successfully treated after failure by other methods, by detaching the subscapularis tendon from its insertion and fastening it to the anterior edge of the deltoid muscle. Ehrlich and Clairmont[2] took a flap of deltoid muscle from the posterior border which they swung under the anterior aspect of the shoulder to strengthen the capsule. They did 4 cases with a recurrence in 1. Armour[3] in a report on Clairmont's operation states that Robert Jones had performed two of these operations in 1912. The flap of deltoid muscle is carried through the quadrilateral axillary space from behind forward and so fastened in front that it makes a sphincter-like ring about the neck of the humerus. The subsequent immobilization of the arm must continue at least two months. The first case operated on by Jones recurred after the dressing was removed, the cause being either insufficient fixation of the muscle or too short an immobilization. The second case obtained a cure. Seidel[4] separated the subscapular muscle, took out an oval piece of the capsule, sutured the edges together, and then covered the entire front of the joint with a piece of transplanted fascia which he sutured to the deltoid and subscapularis. The patient died some time later, and microscopic examination showed that the fascial flap had been preserved. Schultze[5] reported 26 cases of habitual shoulder luxation treated by capsule plication, 7 of which recurred within two or three years. He has come to agree with others who believe that fascial flaps are necessary in addition to the capsule suture.

The influence of the muscles has attracted Selig's attention.[6] He

[1] Ztschr. f. Orthop. Chir., 1908.
[2] Freie Vereinig der Chir. des Congress, Sachsen, 1913.
[3] Liverpool Med. Chir. Jour., 1914, xxxiv, No. 65, p. 100.
[4] Zentralbl. f. Chir., 1913, xl, 1344.
[5] Arch. f. klin. Chir., 1914, Bd. civ, Heft 155, p. 139.
[6] Loc. cit.

criticizes the use of inactive tissue like fascia or the biceps tendon to strengthen the capsule, and says recurrences can be avoided by using active instead of passive material. Ducherne[1] is quoted as stating that the supraspinatus muscle is an elevator of the arm more powerful than is understood, and besides helping the deltoid it also aids in holding the head of the humerus in contact with the joint surface. When the supraspinatus and trapezius have atrophied, during a subsequent raising of the arm the head of the humerus is frequently displaced forward into subluxation. If the surpraspinatus is functionating normally, even when the deltoid is atrophied, the subluxation cannot occur. The scapulohumeral ligament is important in this restraint. Selig advocates an open operation also on an anatomical basis from his standpoint, namely, through an incision in the supraspinous fossa. The trapezius fibers are separated, and the supraspinatus tendon is recognized. This tendon is shortened by plication as much as it can be, and the dislocation does not recur, because the muscle holds the humeral head in place.

Recurrent and habitual dislocations dependent on pathological joint changes, congenital conditions and paralyses, and not the result of traumatic dislocation are not considered in this work.

Old Shoulder Dislocations.—Shoulder dislocations become old at different periods following their luxation. Some can be reduced a month after injury, others have been put back after four months, but as a rule after three months of displacement in the abnormal position the dislocation becomes irreducible and is classed as old. Kocher considers them irreducible and subject for operative reduction as early as five to seven weeks after luxation, yet he reports 25 out of 28 cases reduced by manipulation, 1 over five months after injury.[2]

The obstacles to reduction may comprise any one or a combination of those given under obstacles to recent dislocation. There are in addition the secondary and progressive changes of the displacement. Briefly there are cicatricial contractions of healing scars in the capsule, adhesions to surrounding axillary structures, bone fragments, osteophytic outgrowths, callus within the glenoid, or overgrowth of the glenoid rim. The muscles about the shoulder become shortened, adherent and atrophied and obstruct replacement. A new glenoid cavity with a false joint and considerable function may have developed, and the question arises whether it is better to attempt to restore the head to its customary position and expose the patient to operative risks and possible sepsis with a resulting ankylosis, or to leave the condition as it is. When the arm is rigidly fixed and there are pressure symptoms on axillary structures, the problem becomes one of deciding between excision of the head and a false joint, osteotomy through the neck with a false joint, or better position of the arm and operative replacement.

Non-operative replacement must be tried. The operator must

[1] Physiologie der Bewegungen, Kassel, 1885, S. 61.
[2] Deutsch. Ztschr. f. Chir., 1911, xliv, 581.

bear in mind the dangers of rupture of axillary vessels and nerves, as well as fracture of the humerus. In the cases reduced by Kocher spoken of previously, the humerus was fractured three times. Mr. Robert Jones uses padded iron rings through which the arm is carried, and traction is made with counter-extension of the ring against the scapula and axilla. He has two rings, one arranged for the patient to sit and the other for him to recline under anesthesia. Thomas[1] prefers the older method of traction in abduction and reports 5 cases. He failed to obtain reduction on one side of an old double dislocation. His method is similar to that employed by Jones, but instead of using a firmly fixed and padded metal ring for counter-traction, he steadies the scapula by bracing his feet against it. The abduction method depends largely on the strength of the humerus and the firm scapular fixation, force being applied directly to the shortened portions of the capsule by the traction made in the long axis of the arm. The patient is fully anesthetized by ether, placed on the floor, the arm manipulated slightly to tear the contracted capsule, and traction is made on the arm by Allis's apparatus. The operator braces one foot against the axillary border of the scapula and the other against the acromion and upper border while he pulls in abduction. As the head starts to descend an assistant may aid by pushing down on it. Old dislocations are characterized by a head lying higher than that in recent luxations. The traction in the humeral axis avoids torsion strains and fracture, but it brings the head down near the glenoid level, so that it can be pushed or levered over the edge into the joint. As the pull overcomes the resistance and the head reaches the position near the glenoid the assistant makes pressure outward and backward to force the head over into the joint. Once into the joint the elbow is also pulled upon by the assistant to assure complete reposition while the operator maintains his traction. The indications for attempted reduction of old dislocations, especially by operative means, can be enumerated as (1) pressure symptoms on nerve and vascular structures and (2) cosmetic and functional betterment. If the head is restored to a normal locus, even if the joint is stiff, the scapula permits considerable movement, and muscular atrophy and disfigurement may be overcome. The incisions are anterior by Andrew's and Jonas's method; axillary by those of Langenbeck, Madelung, and Nélaton. The anterior incision offers the most complete and easiest approach to the restricting tissues, the axillary is efficient for resection of the head, but like the posterior incision it does not permit approach to the adherent anterior part of the capsule in the upper anterior axillary space, and it offers little chance for leverage on the head of the bone. A posterior approach also involves division of the scapular spine and reflection of the acromion.

Dollinger, of Budapest, in his first report in 1902,[2] mentioned 19 old shoulder dislocations treated in five years. Six were treated by

[1] Ann. of Surg., lvii, 217.
[2] Deutsch. Ztschr. f. Chir., lxvi, 319.

non-operative method, 2 resulting in fracture of the neck of the bone with no reduction. Of the remaining 13, 3 were treated by resection of the head, and 10 open arthrotomies were done to cut the retracted subscapularis muscle, which he considered the greatest obstacle to reduction. In 1911[1] he made report on 39 operated cases, 33 of which were treated consistently by division of the subscapularis. Eight of these cases were infected, and there was 1 death from injury of the axillary artery; the best results were obtained in the old luxations of not more than two months' standing, for which 50 to 75 per cent. function was obtained. He approached the joint through an incision between the deltoid and pectoralis major. The pectoralis minor is retracted upward and the major down. The spinati, teres minor, and coracobrachialis are now in front of the head. They are retracted, and the subscapularis is brought into view by the rotating of the arm outward. Its tendon is severed and the dislocation is then reduced by Kocher's method, after which the subscapularis is sutured to its insertion.

A large proportion of other operators, especially American surgeons, believe that the fibrous restrictions from torn capsule and periosteum about the displaced head are the cause of irreducibility in these dislocations, and most of them favor open operation by an anterior approach. Jonas[2] reported 11 cases, the greater number of them approached by incision through the deltoid, 1 by the axillary route. Nine cases were operated on, 7 were reduced, and 2 were treated by resection. He believes that the deltoid and supraspinatus offer great resistance to reduction. In 1 case he found the glenoid edge so flattened that the bone gradually slipped out of place again. In all but 2 of his cases the contour of the head was normal, in these 2 there was flattening or a groove in the posterior surface. Three had tearing off of the greater tuberosity. The final outcome of all cases was improvement, although none were restored to full use, a condition which it would be almost impossible to hope for. Schultz and Kuttner found after arthrotomy in recent dislocations that only 12 per cent. to 15 per cent. gave normal function. Pain and circulatory disturbances, however, always disappeared. Some atrophy of the deltoid persisted. Other operative cases have been reported by Pool[3] and Jopson[4] with fair results. Jopson could not make reduction until the anterior and outer fibers of the capsule were incised. Pool advises excising the head for greater freedom of motion, and replacement in normal position for strength, and he suggests preservation of the anterior capsule as much as possible. Hotchkins reported[5] 8 operated cases, 5 reduced after arthrotomy, and 3 resected heads.

Andrews, in 1905, strongly advocated the anterior approach by resection of the pectoralis major muscle close to its insertion after an experience based on radical removal of the breast and a review of the

[1] Ergebnisse der Chir. und Orthop., iii.
[2] Ann. of Surg., li, 890.
[3] Ibid., lv, 626.
[4] Ibid., lviii, 542.
[5] Ibid., April, 1904.

technic of Rearink, Ollier, Körte, Dollinger, Keetley, and others previously mentioned. This approach avoids danger to the axillary vessels and nerves, because they are retracted out of the way after the muscle is severed. The capsule is then cut or nicked with the help of rotatory arm movements, and, after the restrictions are all cut through by a pull of a steel hook passed around the neck, the bone is slipped back into the socket. The pectoralis muscle is then sutured together by mattress stitches, and the arm is put in an immobilizing dressing for two weeks. Cautious use is then commenced, and results are satisfactory. I have reduced three old shoulder dislocations by this method and like the exposure, the opportunity to free adherent vascular structures, and the satisfaction of seeing the head go back into the glenoid. In 1 case I had to incise the capsule and fibrous mass for over two-thirds of its circumference. Function of 30 per cent. to 45 per cent. resulted, and these must be considered fair results as the cases were all of some months' standing.

CHAPTER XVII.

FRACTURE OF THE FOREARM BONES.

(1) At the proximal end: the olecranon; coronoid process of the ulna; head and neck of the radius; (2) The shaft of one or both bones. (3) At the distal end: styloid process of the ulna alone; Colles's fracture of the radius and both bones near the wrist.

1. **Fractures of the Olecranon Process.**—The ulna develops from three ossification centres, as represented in Fig. 243, and injuries of the olecranon rarely occur through the epiphyseal line.

Fig. 243.—Plan of ossification of the ulna. From three centres. (Gray.)

In the series of 10,702 fractures examined by me at the Cook County Hospital the olecranon was concerned in 91 instances, or 0.85 per cent. In 1914 there were 16 instances, 3 of which were complicated by condylar fracture of the humerus. The plane of fracture may run transversely or obliquely across the olecranon at any point from the tip to an inch distal to the coronoid process, passing into the elbow-joint (Figs. 244–247). This plane is generally straight, but it may be irregular. There may be little or no separation, or the fragments may be widely displaced and the proximal fragment pulled up by the contraction of the triceps muscle. In some instances there are two or more fragments, and the fracture is comminuted. If one bears in mind the manner of bone separation under stress of ligamentous pull, it is evident that a large percentage of olecranon fractures are caused not by direct violence but by a sudden increase in tension of the pull of the triceps tendon. Possibly seven out of ten fractures of this process are of the oblique type with little separation of fragments, the plane running into the joint, and exhibit over the olecranon area of skin no evidence of direct trauma. The other 30 per cent. of cases are those in which the fracture is complete; that is, the plane is more directly transverse, and the separation of fragments is distinct. Included in this class

and representing some 10 per cent. of the whole, are the comminuted cases caused by a combination of muscular pull and direct trauma.

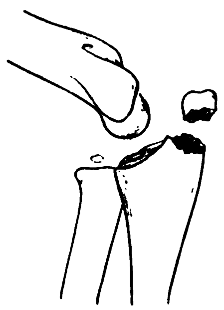


Fig. 244.—Fracture of the olecranon in a child. The upper fragment retracted by the triceps tendon.

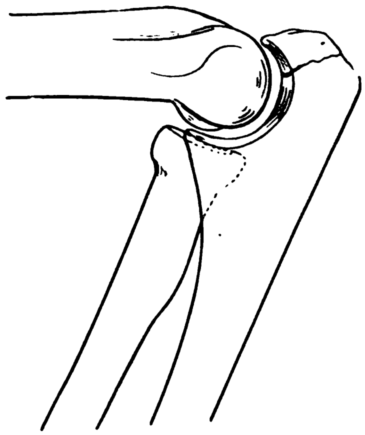


Fig. 245.—Fracture through the epiphyseal line. No separation.

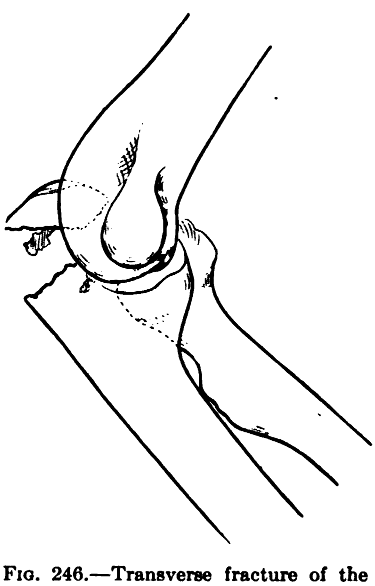


Fig. 246.—Transverse fracture of the olecranon with fragment retraction.

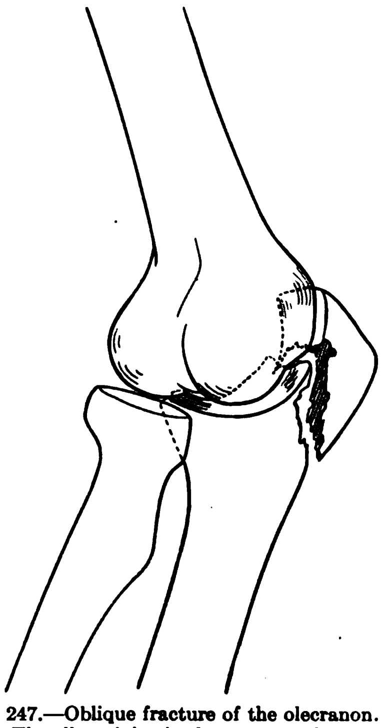


Fig. 247.—Oblique fracture of the olecranon. The elbow-joint is always opened.

When a person falls on the supinated forearm, his muscles instinctively tighten to break the force, and as he receives the impact there,

is a sudden great increase of stress in the region of the triceps insertion on the olecranon. The crushing weight of the fall causes the ulna to be pulled over the end of the humerus as a fulcrum with the triceps rigid, and this causes the bone to give. The line is transverse or oblique, depending on the sharpness with which the weight is suddenly transmitted, the sharper the increased tension, other factors being equal, the more transverse the fracture line. The amount of separation following depends on two conditions, first the amount of tear in the capsular ligament of the elbow-joint, including the periosteal rupture,

FIG. 248.—Fracture of the olecranon and coronoid process and inward dislocation of the elbow. Note the radial head approximating the internal epicondyle, and the olecranon lying directly inside the lower end of the humerus.

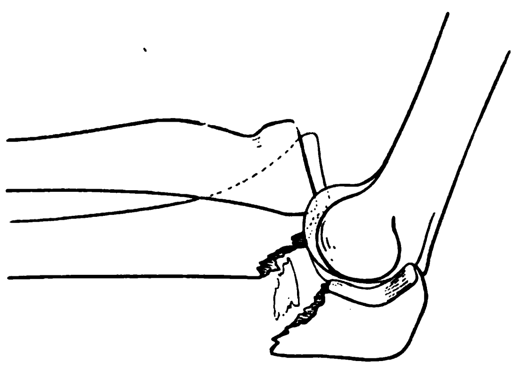


FIG. 249.—Fracture of the olecranon and dislocation of the radius and ulna forward. The olecranon fragment has remained in its relation to the trochlea.

and secondly, the reception of some direct trauma over the olecranon area when the injured elbow comes in contact with the ground. These fractures can be compared with patellar fractures in many ways. The plane of fracture starts most frequently at the narrow portion of the process, its weakest part, and differs from experimentally produced separations following blows by a hammer when the cadaver muscles are lax. These artificial fractures are always comminuted into several fragments, and there is no oblique plane as there is in all fractures arising from torsional violence.

Muscular action by contraction of the triceps has caused this frac-

ture in a person overexerting in throwing a ball or other object. Hyperextension of the forearm may also cause fracture of the olecranon because of the fact that the tip of the process impinges against the olecranon fossa of the humerus. Capsular stretching or tear permits the ulna to extend beyond its usual range, and the tip is split off from within outward. Fracture of a condyle or dislocation forward of the head of the radius may accompany this type (Figs. 248 and 249).

Symptoms and Signs.—Pain in the elbow, swelling and tenderness on pressure over the olecranon, are the common symptoms. Voluntary extension may be limited, especially if there is separation of fragments, and the patient prefers not to make this motion on account of pain, holding the forearm comfortably about two-thirds extended. In recent injury when the plane of separation is complete and the upper fragment is separated, crepitus is easily demonstrated. By flexing the forearm the attendant can see or feel that the upper fragment does not move with the forearm, and in complete fracture he may find a definite sulcus between the fragments into which a finger can be laid.

Much of the swelling is in the olecranon area, the elbow-joint as a whole showing little reaction. After the lapse of two or three days the bursa over the olecranon process may become the seat of swelling, and the skin around becomes edematous and painful, so that it is difficult to diagnose fracture or a traumatic bursitis. The use of the Roentgen rays shows that a large percentage of olecranon injuries are really fractures that have little separation, so that in the pre-Roentgen era there was doubtless a large proportion of cracks through this process which were not recognized as fracture. The heavy capsular and elbow ligaments blend with the periosteal covering of this process and have more to do with the amount of the separation than the pull of the triceps tendon. The bone may be cracked and slightly separated across its continuity, but if there is no accompanying ligamentous or capsular tear, no separation will follow when the forearm is brought into flexion. The process may be badly comminuted and yet not separated, if this ligamentous envelope retains its integrity. The triceps does cause separation, if this tear permits retraction of fragments, and in many cases this action of the muscle is manifested at once. In old cases with separation, the proximal fragment tends to be pulled higher up, as this strong unopposed muscle contracts, but it cannot draw the fragment above the olecranon fossa of the humerus, unless the capsular and periosteal attachments are loosened. Consequently in most cases seen early, before there is pronounced swelling or infiltration, full extension of the forearm with slight pressure down on the upper fragment serves to bring the two into contact, and crepitus is obtained. If the upper fragment has been broken off obliquely, ending in a sharp point and much displacement, this projection may puncture the skin or threaten pressure necrosis, if the olecranon area has been damaged by trauma. Dislocation forward of the ulnar shaft accompanies this type. In fresh injuries there is

sufficient ground for diagnosis of fracture if the power of active extension is diminished and there is present swelling and a persistent point of tenderness, when the process is examined by digital or pencil-end pressure. In old cases the presence of bursitis must be excluded, and a Roentgen picture should be made if possible.

The character of the *repair* of the fracture does not need the discussion it was formerly entitled to, as we now have in the Roentgen rays a means of deciding whether, after due time, a union is bony or fibrous. Furthermore, the extent of restoration of function in the forearm does not depend so much on the question of bony or fibrous union between the fragments as it does on the presence of intra-articular projecting callus, lacerations of the periosteum with the formation of bone deposits into the articular capsule, and a thickening and shrinking of the capsular structure which interfere with joint motion. Practically all olecranon fractures with little separation or with fragments brought into reasonable apposition by treatment result in bony union. This fact I have verified by skiagrams taken in the course of weeks or months after injury. If there is a wide separation of fragments and the fracture is not treated by open operation, fibrous union does result in some cases, and in nearly all of these the functional result is good, if the arm has been treated in extension. In a small proportion complete extension of the forearm is lost, but as the movement of flexion is one of greater importance in function, this partial disability of extension is never noticed. Bony union does not depend so much on the line of fracture or the number and shape of the fragments as it does on proper apposition of them in the treatment. Rarely the periosteum of the tip of the process becomes lacerated, and some callus is thrown out here beneath and possibly into the triceps tendon, which may become adherent to the olecranon fossa and preclude use of the joint. If a strong fibrous union is obtained, this may stretch a little after use, but the triceps take on a little shortening by contraction of the muscle length, and function is satisfactory.

Jones[1] states that the cases which he has treated by wiring do not surpass those treated non-operatively, and that although operation leads to a larger percentage of good anatomical results the difference in functional results of the two methods of treatment is small. The operative results give 77 per cent. good functional results compared with 75 per cent. by non-operative treatment.

Non-union rarely occurs and arises from improper immobilization and effort to approximate the fragments, or the falling between of a piece of periosteum or capsular ligament which had been stripped off the bone. Modern treatment in cases of complete separation eradicates this result. We should expect a happy result from open treatment. Fibrous union of the fragments may be present, but if the capsular and ligamentous structures have healed firmly, and too early

[1] British Med. Jour., December 7, 1912.

use has not resulted in stretching of the scar in these structures, the function may be very good. That non-union is not feared, partly on account of lack of separation and partly of good reduction as evidenced by the roentgenogram, is demonstrated by the sixteen fractures of this process treated at the Cook County Hospital in 1914. But three of these were subjected to open operation, and yet the result in every case was good to excellent.

Stiffness in the joint, incomplete extension or flexion, and pain arise from the conditions mentioned above following intra- and periarticular damage of callus or thickening and are not frequent.

Treatment.—It can be stated that treatment depends largely on the separation of the fragments, because this separation is an indication of the accompanying pathology in the other joint structures. Simple transverse or oblique fracture near the end of the process, the fragments of which are not separated and do not tend to become so when the forearm is flexed, can be supported in a sling with the arm nearly at a right angle. If this position tends to cause fragment distraction, the forearm is maintained in a position of extension which allows approximation and is held there by a light moulded plaster-of-Pairs splint applied on either surface of the limb. If the local reaction is severe and the swelling and joint distention are the most marked symptoms, the arm is placed on a pillow in a comfortable position and an ice-bag is applied for a few days until the swelling subsides. The joint may be drained by the trephining of the olecranon according to Doberaner's suggestion in suppurating elbows.[1] In a few cases of little separation the fragments cannot be approximated unless complete extension of the forearm is obtained.

If the process is comminuted or the oblique upper fragment threatens skin puncture, the covering of the elbow must be kept aseptic by an alcohol wash or half-strength tincture of iodine and dry sterile dressings. Then complete extension is obtained by an anterior moulded plaster splint, and the position of fragments is checked by a roentgenogram. The strapping of the upper fragment as a means of pulling it down or preventing tipping can be accomplished by the use of U-shaped, narrow strips of adhesive tape or of long pieces which cross just above the olecranon tip and run well down on to the forearm, or of a small pad pressing down on the top of the olecranon and strapped firmly in position.

Hooks, locked into the upper fragment or caught in the triceps tendon and extended to attachment in a permanent plaster dressing or cuff below, are not used in modern practice. These are much like Malgaigne's hooks in treatment of the patella. I have never seen them used, and while they are undoubtedly of value where open treatment could not be obtained, they are practically never employed.

Open treatment is reserved for those cases of wide separation, comminution, tilting, or presence of a fragment loose in the joint which

[1] Münch. med. Wchnschr., lxii, No. 14.

cannot be fully and satisfactorily reduced and held by splinting and strapping. One very good method encircles all fragments with a silver wire which passes through the triceps tendon above and through a hole drilled in the transverse axis of ulnar shaft below. This when tightened, brings all fragments and the capsular structures into good position and the operation can be performed through a two-inch incision on the point of the elbow. The forearm is put up in three-quarters extension with an anterior moulded plaster splint. Silk or linen may be used also for this suture, and it is better applied through the triceps tendon than through a hole bored in the uppper fragment, as this may be split in the process and by the tendinous route but one hole has to be made in the bone. Small loops of wire in the long axis of the ulna do not hold well, are difficult to introduce, and lie very superficially.

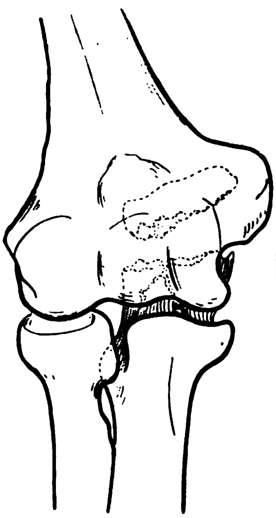


Fig. 250.—Anteroposterior view of comminuted olecranon with separation of fragments

Fig. 251.—Repair of preceding by ivory peg—lateral view.

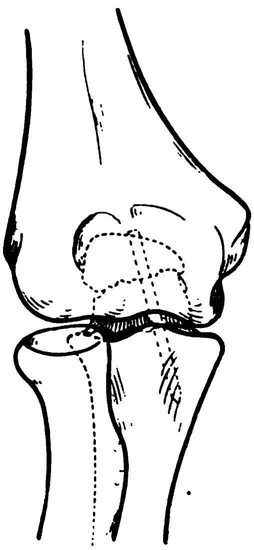


Fig. 252.—Anteroposterior view of repair by ivory peg.

In comminuted fractures I have sometimes used ivory pegs or metal nails, preferring the former (see Figs. 250, 251, and 252). The peg is introduced through a small incision over the upper fragment, and, after a drill hole has prepared the way, driven down into the ulnar shaft. The arm must be held in extension during this operation, and care must be taken to avoid the joint surface. The arm is dressed in extension. On the whole the encircling wire suture is the best treatment if operation is indicated, as it tucks all fragments snugly together and also includes the other structures. Usually it holds very firmly, and passive motion can be started on the eighth or ninth day in the direction of flexion.

Course.—In simple treatment after the fourteenth day the splint is removed and a small amount of passive motion is given the elbow. This must not produce pain nor rupture the delicate adhesions between fragments. Each day this is repeated, and in the third week massage is begun. Union should be complete by the end of the fifth week, and active use can then be inaugurated.

After open operation the course is about the same. If the skin is closed with clips, these are all taken out by the end of the first week. After the second week motion and massage are given as above, and if wide separation was treated, the splint should be left on five or six weeks, when bony or firm fibrous union will be present. Attainment of use of the arm requires some additional three weeks.

Old cases of non-union, or of fibrous union with impaired extension power or interference with joint movement, are treated by more elaborate operation. If it is a case of simple stretched fibrous union with normal joint structures, this band is dissected out, the ends of the fragments freshened by a very sharp chisel, and the fragments wired together. If interference with joint function is found to be caused by excessive callus, thickened capsular structures, or the tilting of a fragment into the joint surface, these must be dealt with as found, and the possibility of capsulotomy or the insertion of fat and fascia, as in arthroplasty, must be considered after bony excess is chiseled away, that new adhesions may not form.

Epiphyseal Separation.—The epiphysis of the olecranon shows beginning calcification in roentgenograms of eight-year-old children; by the tenth year there is a well-marked centre occupying one-third of the process, and union takes place with the rest of the olecranon in the seventeenth year (Poland and Gray). Of the 16 cases of olecranon fracture mentioned above, 4 were in patients in the eighth or ninth year, 1 was in a fourteen-year-old boy; and 2 of these were distinct epiphyseal separations. This has been considered a rare epiphyseal injury and is caused by stress on the triceps insertion as in olecranon fractures, or by a sharp blow of direct violence, as in a fall with the forearm in flexion. In childhood the olecranon is proportionately smaller in size and its projection less prominent than in adults, so that when the forearm is flexed to a right angle, the posterior edge of the epiphysis in children up to fourteen years of age, lies anterior to the plane of the humeral shaft and its epicondyles. Consequently, when a child less than fourteen or fifteen years old falls on the elbow, he is more apt to receive a fracture of the condyles than of the olecranon, as the former processes are exposed to the violence. Hyperextension with resulting dislocation of the head of the radius may also cause this epiphysis to separate.

A case in a nine-year-old boy has been reported by Skillern,[1] and in Holmes's *System of Surgery*,[2] out of a total of 2705 fractures 76 were of the olecranon, 10 of those occurring before the tenth year of age.

[1] Ann. of Surg., liii, 873.

[2] 1881, i, 845.

If the diastasis between fragments is great and there is reason to believe that periosteal or other tissues have fallen between the fragments, open operation should be the treatment, as a means not only of promoting union but of preserving the growing function. In minor separations, treatment in a moulded plaster splint in three-quarters extension for two weeks is sufficient.

Fracture of the Coronoid Process.—This fracture is also considered rare, and there are few references to it in the literature. Robert Jones[1] says he has encountered several instances of it and believes that it is much more frequent than reports show. He had one case followed by a traumatic myositis ossificans and has knowledge of several cases followed by a fresh accumulation of bone after removal by operation. In the last year I have seen two cases of this injury: one a linear crack from the proximal edge of the process running down into the shaft of the bone, and the other a transverse fracture with a fair-sized fragment completely displaced forward. Neither of these cases was accompanied by dislocation at the elbow, and in cases of old posterior elbow dislocations which I have operated on I have never found a separate fragment, or evidence of fracture of the coronoid, although I have looked for them. Many authors assert that the dislocation is necessary to cause this fracture (Fig. 253). Indirect violence transmitted from the forearm is the usual cause, although direct violence might act.

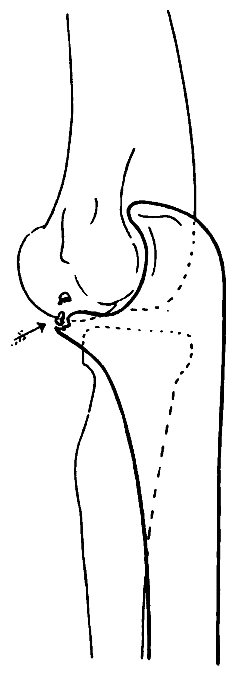


FIG. 253.—Fracture of the coronoid process. Note the tendency of fragments to wander into the joint.

Stimson[2] quotes the results of Lotzbeck, who obtained fracture of the coronoid in five out of ten attempts by striking the palm of the hand when the elbow was fixed in a slightly flexed position. A sudden sharp contraction of the brachialis anticus muscle, which is attached on the anterior surface near the base of this process, may cause a splitting off of the bone with an oblique plane of separation. In these cases, if the separation is complete, the distal point of the fragment is tilted up, whereas in fracture caused by indirect or direct violence and with a more transverse separation, the fragment is held down in place beneath the insertion of this muscle, which remains intact. To permit displacement, tearing of the joint capsule as well as the periosteum must take place, and it is these structures which retain connection with the fragment and supply it with nutrition and promote union.

[1] Proc. Roy. Soc. Med., England, December, 1910.
[2] Fractures and Dislocations, 1913, p. 245.

Symptoms and Diagnosis.—In linear or sprain fracture with no separation there is some swelling over the anterior aspect of the elbow and pain on pressure over the process. Rapid flexion of the arm may be painful. The Roentgen examination gives the only sure diagnosis. If a fragment has been separated and is displaced forward, it may be felt as a freely movable mass beneath the brachialis tendon, or crepitus may be obtained by the surgeon rubbing the coronoid process back and forth with the forearm in partial flexion. It may be possible to push the loose fragment into position, but recurrence of the displacement usually follows at once, if the pressure is removed.

Treatment.—Treatment consists in the fixing of the arm in a moulded plaster splint in a position of flexion, about 60 degrees for cases of moderate displacement, or in full flexion if the fragment tends to be dislocated completely forward. If the process is merely cracked or there is no separation, fixation in a sling with the forearm at a right angle is maintained until soreness has left the joint. Active use is cautiously begun. In old cases if the fragment interferes with joint movement by mechanical pressure it should be excised.

Fractures of the Head and Neck of the Radius.—These fractures have been rare for the most part on account of the difficulty of diagnosis before the advent of the Roentgen rays, only 21 cases being reported up to 1880, although the first case was known in 1834. Most of these 21 cases were the result of postmortem examination. In 1905 Thomas[1] collected 45 cases in the literature. Since that time many other reports have come, the largest being that of Stocklin, who cited 26 cases. In a large city hospital where all suspected fractures or obscure injuries are subjected to Roentgen examination, these fractures are found every few months. In 1914 at the Cook County Hospital there were 2 cases of fracture of the head and 1 of the neck, also a buckling fracture high up near the neck.

The radial head rotates through an arc of nearly 180 degrees held by a sling formed by the lesser sigmoid cavity of the ulna and the orbicular ligament. Injuries of the head and neck consequently often lead to interference with rotation of the forearm, especially supination or flexion and extension of the elbow. The line of fracture is usually vertical and occurs within the orbicular ligament, or it may be transverse, complete or incomplete, so that a fragment is split off freely. Children are prone to the incomplete transverse type and the subperiosteal fracture with buckling of the neck. Epiphyseal separation is also found, while in adults the longitudinal, complete or incomplete variety is the usual finding. If a fragment is split off by the longitudinal cracks, it usually retains its connection to the shaft by periosteum or ligament shreds.

Causes.—Blows of direct violence, or a fall on the elbow which results in direct violence to the head of the bone is the most frequent cause, especially in fractures of the neck or transverse fractures of

[1] Univ. of Penn. Med. Bull., xviii.

children. Small fragments may be chipped off the head from direct violence in dislocation of the radius either by impingement against the capitellum of the humerus or possibly by the mechanism of sprain fracture, a pulling out of the bony surface by ligamentous attachment (Figs. 254 and 255). Stimson believes that longitudinal splitting of the head and separation of fragments is caused by violent wrenching of the forearm and cites 5 cases seen by him (Figs. 256 and 257). Falls on the palm of the hand with resulting indirect violence on the radial head are disputed mechanisms, and in the subperiosteal or buckling type in children these are probably the cause.

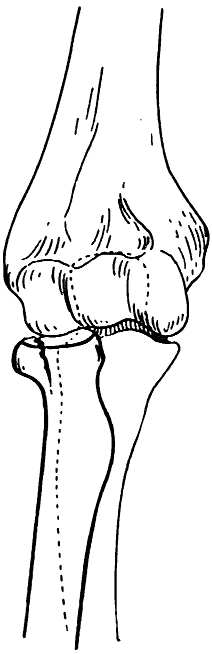


FIG. 254. — Longitudinal fracture of the radial head, a condition easily overooked. This is a true joint fracture.

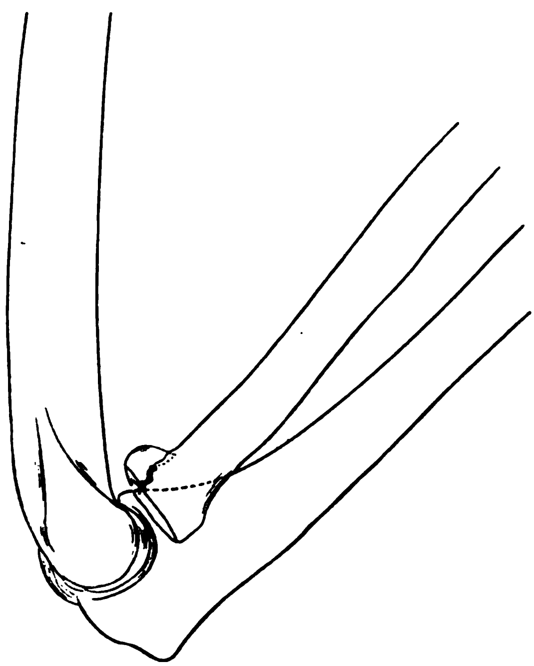


FIG. 255.—Lateral view of a similar fracture shown in the preceding picture.

In fissures or longitudinal cracks of the head and neck there is no displacement of fragments, and if the line is strictly within the orbital ligament there is no crepitus. On attempts at supination of the forearm, however, there is pain and muscular spasm, so that this motion is greatly limited. There is also distinct pain on direct pressure over the radial head, aggravated when the hand is grasped by the examiner and the forearm rotated. If transverse fracture exists *below* the orbicular ligament, there is more separation of fragments, the head may be displaced outward and forward, or a piece

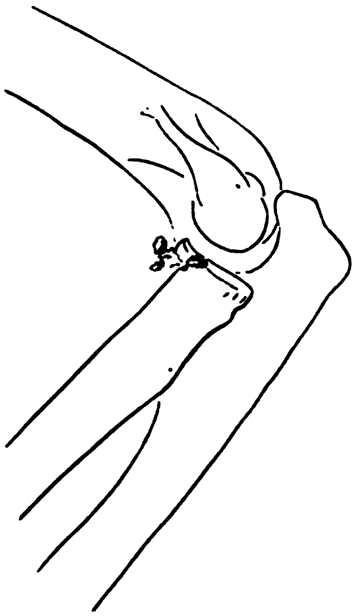


FIG. 256.—Small comminuted fragments clipped off the radial head by striking the capitellum.

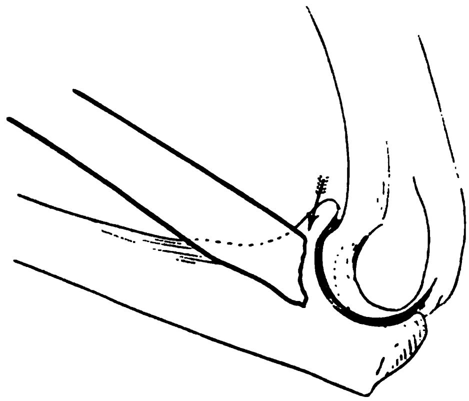


FIG. 257.—Postoperative picture of the preceding showing removal of the head of the radius. There was fair ultimate function.

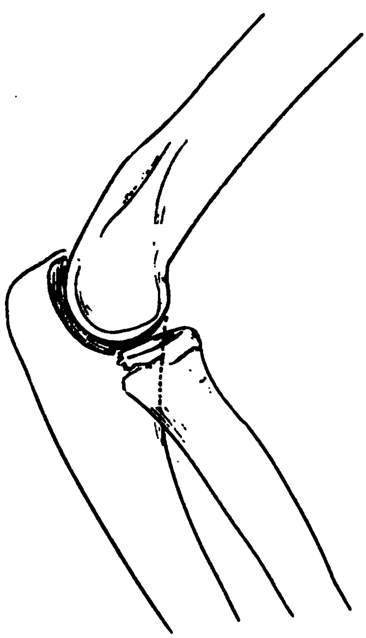


FIG. 258.—Incomplete fracture of the radial head caused by muscular action and indirect violence.

broken out may come to lie at any point of the joint anteriorly or laterally, especially if elbow dislocation has been a complication. In

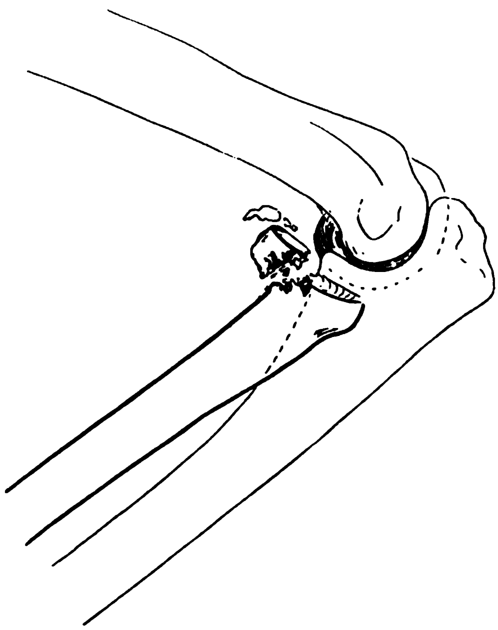


FIG. 259.—Separation of a fragment from the head caused by muscular action and indirect violence.

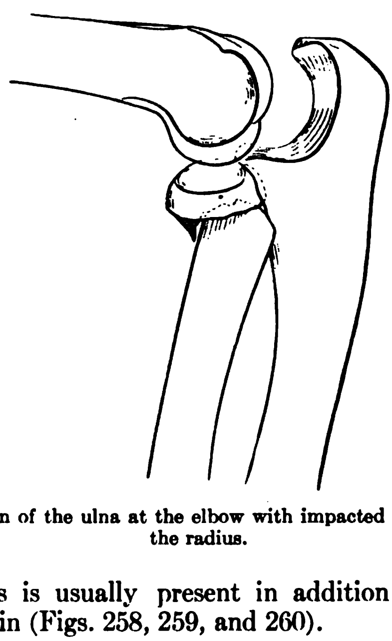


FIG. 260.—Subluxation of the ulna at the elbow with impacted fracture of the head of the radius.

this type crepitus is usually present in addition to the restricted supination and pain (Figs. 258, 259, and 260).

Broken-off heads have united, always with displacement and loss of function. Sometimes the bone ends become smoothed over, and non-union results with a varying degree of functional interference. The radial nerve may become involved in the callus or be injured primarily. (See Dislocations of Head of Radius.)

Diagnosis.—In the fissure type of fracture of the head without displacement diagnosis is made on the limited rotation of the forearm, especially the painful supination, the evidence of blood extravasation about the head, and a point of great tenderness when pressure is made by an examining finger. Transverse fracture of the head with displacement of a fragment or fracture through the neck which displaces the whole head have in addition to the above findings a crepitus when the forearm is rotated, or the loose fragment is distinctly palpable in the joint structures near the olecranon. Jarring the forearm in its long axis also gives pain at the site of injury, and the type of fracture is settled by the Roentgen rays.

Treatment.—Treatment should aim to preserve function. If the fracture is seen early and there is a loose fragment at any part of the joint, it should be removed at once by operation. Linear cracks with no separation demand but little treatment; immobilization should be short and *active use* should be made of the joint after ten days to avoid shrinking of the capsule and restricted motion. In children the results are frequently very happy, even if the Roentgen picture promises poorly, but some restriction of forearm movement always follows. Stoecklin,[1] out of 26 cases performed operation in 12, leaving for conservative treatment those cases which were the milder, and the results were good for all except 1. Of the operated cases, which were severe, the results were very bad in 3 instances, with great restriction of supination. A series of 19 cases was reported by Hitzrot.[2] The best results were obtained in the 4 cases in which the loose fragments or whole head were removed; the greater the amount of bone removed, the better the result. Hammond[3] agrees with this. Of the 15 cases treated conservatively, nearly all lost at least one-half of their forearm rotation. Radical and early operative removal of the loose head is the most satisfactory treatment.

Fractures of the Shaft and Lower Ends.—Colles's Fracture.—In the review of 10,702 fractures at the Cook County Hospital the radius was found to be involved 826 times, or 7.7 per cent., and the ulna 414 times, or 3.8 per cent. The lesions were distributed as follows:

The radius alone, in its shaft or head	158	times
Colles's fracture	533	"
Fractures of both bones of forearm	135	"
The ulna	414	"
The shaft of the bone	188	"
Olecranon fractures	91	
Fractures of both bones of the forearm	135	"

[1] Loc. cit.
[2] Ann. of Surg., March, 1912.
[3] Ibid., lii, 207.

During 1914 many patients, especially those with Colles's fracture, were treated without being entered on the permanent records. The fractures were reduced in the wards, the position determined by roentgenogram, and the individual treated as an out-patient. In that year there are records of 86 cases of fracture of the radius distributed as follows:

The head	2 cases
The neck	1 "
Buckling fracture near head	1 "
Colles's fracture	54 "
All others, mostly middle and upper third	28 "

Fracture of the ulnar styloid accompanied 15 of the Colles's fractures, and the carpal scaphoid was fractured in connection with 1. There were 2 instances of double Colles.

The ulna was broken alone or as indicated, 31 times, the site of fracture being distributed as follows:

Olecranon	15 cases
Complicated by fracture of the humeral condyle	2 times
Ulnar styloid alone	2 cases
Coronoid process	2 "
Upper and middle third	12 "

Fractures involving *both bones* of the forearm were 51 in number, 5 of which were open. These were:

Radial head and coronoid of ulna	1 case
Green stick	1 "
Lower epiphyseal separation	1 "
Double fracture both forearm bones	1 "
Both bone fracture of other levels	47 "

Most fractures of the shaft of bones involve the middle or lower thirds, and the ulna is usually broken lower down than the radius. When fracture force affects the forearm low down, the radius alone is usually broken (Figs. 261 and 262).

Causes.—Direct violence by a sharp blow across the outstretched forearm, twisting violence from a catching of the forearm in a wheel or machinery, or forcible compression of the forearm across an edge or solid mass causes the compression fractures. Indirect violence from falls on the hand or from muscular action and body weight cause the torsion fractures. These may be combined as in the leg, so that the torsion and compression mechanism act together. A third class of fracture, many of which were formerly called green-stick fracture, are now known to be buckling or compression fractures in the longitudinal axis of bones (Figs. 263–267). These occur in youths or adolescents and arise from a telescoping action of the cortex which gives way and bulges out laterally. (See figure of buckling fracture of humerus, and also figure of fracture of radius.) Rarely this involves the whole circumference of the cortex, and the slight shortening is uniform,

so that there is no axial deviation of the bone; in many cases involving the forearm bones this buckling involves but one side of the shaft and there is an axial deviation.

Skillern[1] has attempted to isolate a group of forearm fractures in children which are characterized by complete fracture of the lower third of the radius with dorsal and lateral displacement of the lower

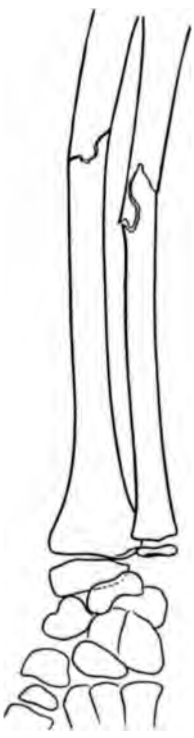


Fig. 261. — Fracture of both bones at about the middle caused by direct violence. The plane of fracture in the ulna is lower than in the radius.

Fig. 262.—A typical fracture of both forearm bones in a child, transverse in type, little separation, ulna fracture lower than the radial. Untoward manipulation of this fracture might produce a serious deformity.

fragment and an incomplete green-stick fracture of the inner side of the ulna at a higher level. These are supposed to constitute 13 per cent. of all forearm fractures. They are the result of the compression and torsion mechanism and are really quite typical because the child falls on the hand—the radius is broken by indirect compression, and the ulna takes up the torsional stress at a higher level when the radial

[1] Ann. of Surg., lxi, No. 2.

support is lost. Fig. 268 represents a fracture of this character in which the radial epiphysis has been displaced and there is a buckling fracture of the inner edge of the ulna. I believe that these fractures are relatively rare.

Pathology.—The displacement of fragments in fracture of both bones may assume any of the usual varieties. In simple compression fracture without separation (see Fig. 262) the two bones are bent

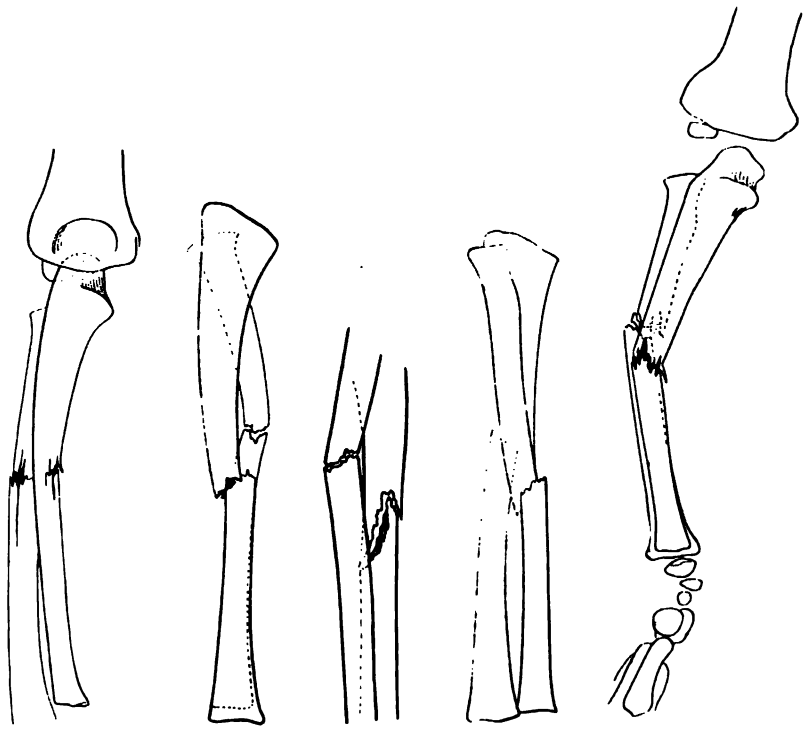


Fig. 263 Fig. 264 Fig. 265 Fig. 266 Fig. 267

Fig. 263.—A more delicate type of fracture in a child. In the ulna there is a true green-stick fracture.

Fig. 264.—Complete fracture of the shafts of both bone with angular deformity.

Fig. 265.—A frequently found type of fracture, both forearm bones.

Fig. 266.—A lateral view, the ulna broken higher up. Axial rotation and overlapping.

Fig. 267.—Angular deformity and slight rotation. The ulna is broken lower than the radius. Very little torsion in the mechanism.

at an angle in accordance with the direction of the causative trauma. If there is complete loss of continuity, a triangular piece may be split off, as in other bones, and there is angularity and overriding, giving shortening as great as two and a half inches in the forearm (Fig. 269). Torsion results in spiral fractures which tend to override. On account of the surrounding muscles and the interosseous ligament, displacements are both restricted and complicated. An adult man with a heavy muscular forearm always presents marked deformity

and overriding in fracture of both bones. The radius may present rotatory displacement caused by the upper fragments being pulled into supination by the biceps muscle and the lower fragments being pulled into relative pronation by the pronator teres muscle when the line of break lies above its insertion. (See Fracture of Radial Shaft.) Healing in this position would greatly restrict rotation of the forearm. Transverse fracture may give much angular deformity, and is often accompanied by overriding. If the four bone ends are directed

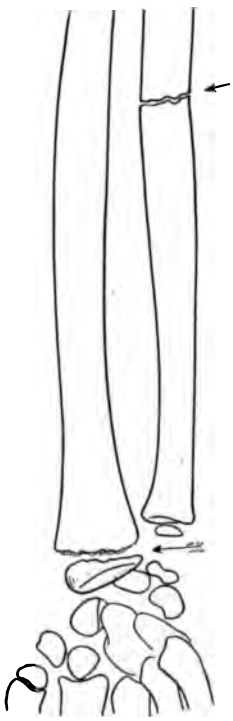


Fig. 268.—Displacement of the lower epiphysis of the radius with linear compression fracture of the upper part of the ulna.

Fig. 269.—Overriding fracture of both bones in an adult forearm. Note the rotation.

in the same lateral inclination there is also marked angular deformity, and the most undesirable displacement of all is lateral angulation of the four bone ends toward each other. If this position remains uncorrected, there is a bony mass in the forearm when all are grown together, and rotation is completely lost. Nerve injury is rare.

Symptoms and Diagnosis.—There is always great loss of function, pain, deformity, a point of abnormal movement, and frequently crepitus. Usually the fracture is apparent at a glance, although it may not be so easy to decide whether both bones are completely

broken or not. The examiner should clasp the injured hand in his corresponding hand and by gentle rotation, the thumb of his other hand palpating along the radial side of the patient's forearm, discover the condition of the radius and the point of the break in it. The ulna, which does not move in rotation and which lies superficially, can next be palpated in its whole length and its condition determined.

In children, or in non-muscular forearms the diagnosis can readily be made, and the course is usually a progressive one to a prompt union, in four or five weeks. In muscular adults diagnosis and reduction are more difficult, and complications are frequent. Overriding with angulation of the bone ends, comminution, or great swelling and displacement lead to trouble. Bony union with deformity may occur, causing lack of rotation or interference with muscular action in the hand, the tendons of the forearm having become adherent to the callus. Great displacement results in non-union frequently, and there is a flail-like joint in the forearm which permits but a few degrees of motion and which weakens the power of the hand. Volkmann's ischemic contracture (see chapter on Pathology) or gangrene of the extremity is also not an unusual complication when treatment is not thoughtfully given and splints are put on too tight and not inspected frequently. If the cause of fracture is direct violence, the splints may cause a pressure necrosis at the point of application of the force, and I have seen several cases where an area two inches in diameter has sloughed out after two or three weeks from splint compression. This may leave the fracture site exposed and cause infection in the bone. The gangrene may be more serious and involve all the tissues distal to the fracture. In superficial ulceration and infection the tendon sheaths and muscles become involved, and contractions, with matted tissues adherent to each other and the bone, result with great loss of function. Secondary amputation may be demanded by a suppurative process which threatens life.

Injury of these bones requires constant attention until the danger of compression from swelling within, or from the light bandage which takes on the contour of the forearm is past. The prognosis is also influenced by too early attempts at use or by the support of the forearm in a sling from the neck which permits gravity to drag the hand down and cause a recurrence of the deformity before the callus has become hardened. This recurrence of angularity or its persistence is the most difficult problem in fracture of both forearm bones. Rotation is accomplished by movement of the radius alone, and in complete pronation the radius crosses over the ulna in an oblique line, while in complete supination the bones lie practically parallel and are separated by their greatest distance. When the fracture results in angulation of the bones in the middle third of their shaft, the interosseous membrane restricts the radius from describing a larger arc away from the ulna in supination, and this action is consequently greatly lessened. Ossification of the interosseous membrane and adherence of fascial and muscle sheaths also has an influence.

If the fracture of both bones is at the same level and from direct violence, all four bone ends may become ossified together to the detriment of forearm rotation and hand function. It is not necessary

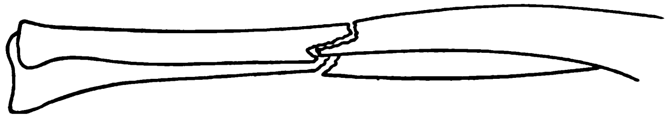


Fig. 270.—Lateral view of a similar transverse fracture of both bones in a young adult after reduction. An excellent result.

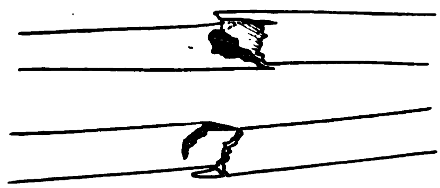


Fig. 271.—First-class non-operative reduction of fracture of forearm bones.

for the fragments of the two bones to be in contact for this unfortunate result to come about, as the periosteum on the inner surfaces may be split, comminution may drive small fragments toward the opposite bone, or osteogenetic cells may wander out into the interosseous membrane from both sides and a firm union follow clear across the space between all fragments.

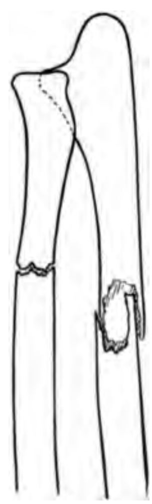


Fig. 272.—Reduction of forearm fracture in a child by manipulation.

Delayed union is usually the result of improper treatment, insufficient reduction, or too early attempts at use.

Treatment.—The indication for treatment is the correction of overriding and shortening and angularity of the bones. When the forearm is flexed at a right angle, an assistant can make good counter-extension by holding the arm while the surgeon grasps the hand of the patient and makes extension. The thumb of the other hand grasps the flexor surface of the fractured forearm, while the fingers are used for pressure on the dorsum. Careful extension is made in the direction of the axis of the distal fragment, the thumb and fingers attempt to straighten out the angularity or correct the overriding, and while the pulling force is at its height the forearm is supinated to bring the bones into position of greatest separation (Figs. 270, 271, and 272). Anterior or posterior angularity can often be nicely corrected by this manipulation, but if much overriding or comminution of the bones exist, it may be impossible to secure end-to-end reduction of the bone and the efforts made may cause greater displacement in an opposite

direction if the force is rough, or may result in the four bone ends being angulated together.

After the surgeon is satisfied with reduction, he must accomplish fixation in this position without disturbing the result obtained. The position of supination affords usually the best anatomical replacement, and while the position midway between pronation and supination with forearm at right angle to the arm is sufficient in those fractures with little displacement and easy reduction, it does not suffice in the more difficult cases. This midway position is the most natural and comfortable one that the arm can assume for any period of time, and it does not become irksome. To obtain greater separation between the bones the position of supination is decidedly better. (See Fracture of Radius Shaft.) Wooden splints of width sufficient to overlap the full breadth of the forearm will hold position firmly. Both the splints and the arm must be well padded with cotton that pressure may be avoided, and the forearm must not be bound by a circular bandage next to the skin. Such a bandage causes constriction if swelling follows reduction by manipulation; it covers up the forearm and disguises the position of the bones and also tends to press the bones together, no matter how loosely it is applied. Wooden or other splints with a padded linear ridge to fit between the bones have no value. If two broad wooden splints are applied, the posterior comes to the wrist from the front of the elbow, while the splint on the flexor surface extends from elbow to the base of the fingers, and the whole is strapped together by adhesive tape and makes a box-like appearance. In spite of padding this splint gives pressure and causes much more atrophy and other changes in the forearm muscles than moulded plaster. A plaster splint moulded in two pieces, one on either side of the forearm extending up on to the arm above and fastened in the same manner with adhesive tape, is lighter and easier to carry. Any splint applied after reduction must be observed repeatedly and removed in a few days for investigation of the condition of the forearm. A Roentgen picture is very desirable in forearm fractures; if but a limited number can be taken, it is much better to wait until the displacement has been corrected and then make a checking picture. Reduction results which seem good clinically may be glaringly at fault under the Roentgen rays and the surgeon may be guided in further treatment or advice and prognosis by his checking picture. It is not infrequent to make a half-dozen attempts to reduce these fractures of both bones before a satisfactory position is obtained or operative treatment is decided upon.

In fractures of the upper third the attendant may maintain reduction by continuous traction, putting the patient to bed, supinating the arm, and putting on adhesive strips to pull the arm out at a right angle *while in supination*. A strap or band for counter-extension must hold the patient from giving toward the weight on the arm.

Supination is also obtained in cases where reduction can be made and overriding does not tend to recur, by the attendant putting the

patient to bed, abducting the arm, turning the forearm over into a supine position, and letting it lie there. This causes much confinement; the same position can be maintained by the moulded plaster. (See Fracture of the Radial Shaft Alone.) Circular casts should not be used on forearm fractures.

After three weeks in splints, with frequent inspections as to pressure, condition of the skin and position of fragments, massage should be started, removing the splint for a half-hour daily. It is a mistake in most cases to remove splints before five weeks. I have seen several

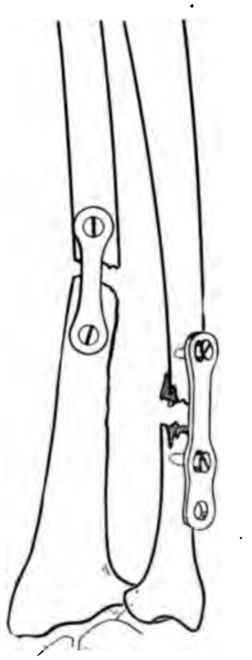


Fig. 273.—An example of plating not to be copied. Bone ends are not approximated; screws are loose and not fully inserted; plates give no stability.

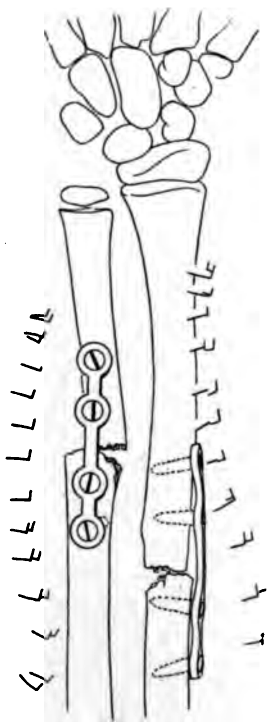


Fig. 274.—An unwise use of heavy plates in the delicate forearm bones of a child.

recurring deformities after this period when callus was apparently firm, brought on by too early attempts at use or the wearing of the arm in a sling which allowed the hand to hang unsupported.

Certain cases of overriding or oblique and comminuted fractures resist all attempts at manipulative reduction. These fractures should be treated by open operation and simple reposition, without a shortening of or interfering with the bones in any way, provided the ends can be made to remain in alignment by this means. Pieces of periosteum lying between fragments are removed. Sometimes a small loop of wire will hold a bad displacement. Lane plates have been

implanted on the forearm bones with excellent reposition of fragments, but a very large percentage of these plates become infected or lead to trouble which causes their early removal, and a longer convalescence follows than after other methods. I do not believe that plates have any place in forearm fractures (Figs. 273 and 274).

The best method of operative fixation is by the intramedullary splint. Separate incision is made over each bone at the site of fracture, on the dorsum of the forearm. The breaks are exposed through as small an incision as possible with the least injury to muscles and other tissues. They are then turned out of the wound, and if the shaft is not split, the medullary cavity is very slightly scraped out and a delicate peg is inserted. If the bones are broken at different levels,

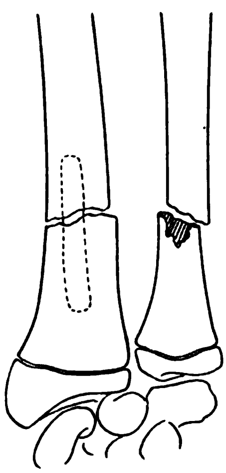


Fig. 275.—Repair of fracture of forearm bones by an intramedullary splint in the radius.

Fig. 276.—Lateral view of the preceding.

it may be sufficient to peg one bone, usually the radius, get it into perfect alignment, and attempt to set the ulna by the dressing, or by an incision over it also, get approximation by wire or kangaroo tendon (see Figs. 275 and 276).

If the bones are broken on the same level it is possible to insert an intramedullary peg into both bones simultaneously, having all four bone ends exposed and sticking out at the same time through two incisions (Fig. 277). This I have done once but know of no other case on record (Fig. 278). The usual splints are used after operation, and the same precautions are taken as if no open surgery had been performed.

Open fractures of both bones of the forearm are treated in accordance with the instructions in the chapter on Treatment. If it is possible

to maintain some extension on the forearm in the manner described above, it is wise to do so until the wounds are healed. Subsequent operations to correct deformities can be undertaken later with safety.

Fracture of the Shaft of the Ulna.—This is caused by direct violence, as falls on the ulna, or to sharp blows received on the forearm when a person is warding off threatened injuries to the head. These fractures are seen as the result of clubbing by policemen or slugging by holdup men with shotted leather or pieces of wrapped lead pipe.

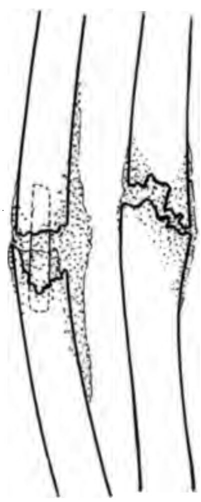


Fig. 277.—Final result in a case where one bone was fixed with an intramedullary splint. Although the callus seems abundant, there was an excellent clinical and functional result.

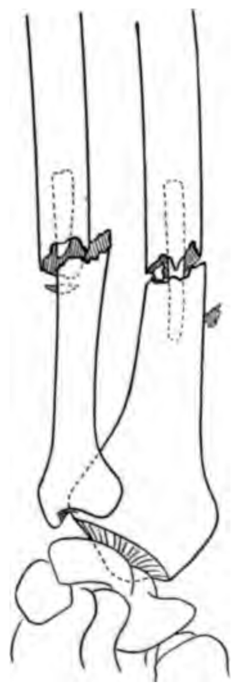


Fig. 278.—Simultaneous intramedullary pegging of both forearm bones. The peg in the ulna failed to hold because a small fragment of the shaft broke out as the reduction was made. Good result.

Pathology.—The fracture is frequently open. The plane of fracture may be transverse, oblique, or comminuted, and there is not a great tendency to displacement, although the lower fragment is frequently drawn over toward the radius by the pronator quadratus muscle (Figs. 279, 280, 281, and 282). As this is a compression fracture, a small triangular piece may be broken out, or the fracture may be but a linear crack.

Symptoms.—The principal symptom is loss of active forcible extension of the forearm, if complete solution of continuity has occurred. In fracture of lesser degree or cracks there may be little interference with function, but use is painful, and there is pain on pressure over

the injured joint. As the radius is not broken, it acts as a splint in the forearm and prevents shortening. By following the shaft of the ulna with the examining finger the surgeon finds the painful spot or a depression or angularity in the bone. Forcible manipulation may

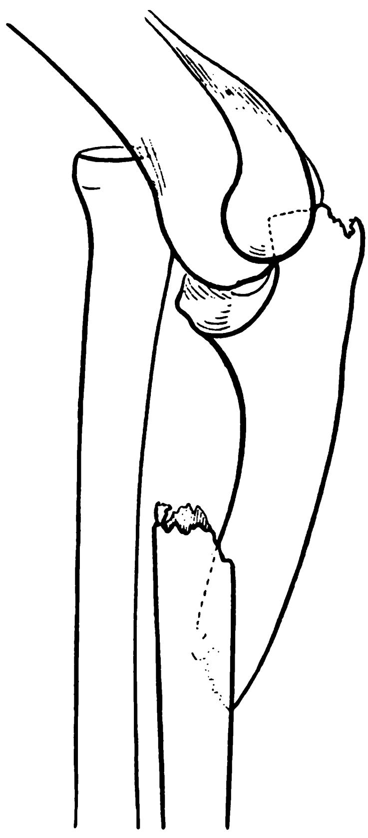


Fig. 279.—Oblique fracture of the shaft of the ulna. The lower fragment is drawn toward the radius and the point of the olecranon shows evidence of injury.

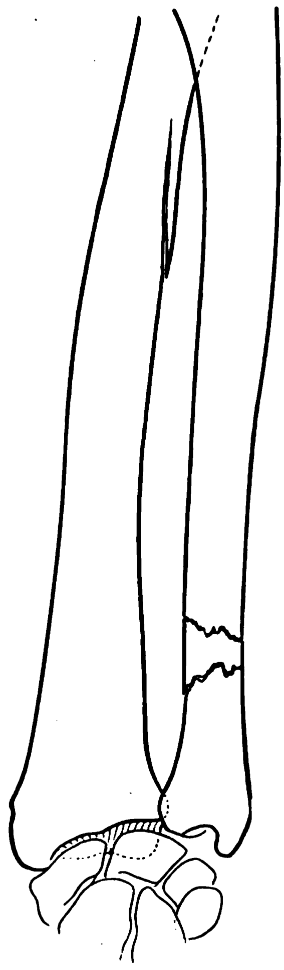


Fig. 280.—Linear transverse fracture of the ulna alone in an adult arm, caused by direct violence. High up in the radius is an incomplete plane of fracture, green stick in character.

elicit crepitus, or a false point of movement can be demonstrated in the shaft.

This fracture frequently accompanies dislocations of the head of the radius forward and is not recognized on account of the more

30

severe injury. Fisk[1] records an unrecognized case which was followed by Volkmann's contracture. He opened and freshened the ulnar fracture and then tried to reduce the head of the radius but was unable to do so, although the capsule of the elbow-joint was opened. The head was excised and the ulna was wired, but improvement was very slow. Another interesting case was reported by Stetten,[2] of fracture of the ulna at the upper and middle third in a nineteen-year-old boy. This was accompanied by forward dislocation of the radial head and paralysis of the *radial nerve*. On operation it was found that the head of the radius had pushed inward the two divisions of the musculospiral, and when the radial and posterior interosseous were freed and the head resected a perfect result followed within three years. (See Dislocations of Head of Radius.)

The literature contains about 140 cases of fracture of the ulna complicated by dislocation of the radial head, so that all cases of the latter injury should be scrutinized for the

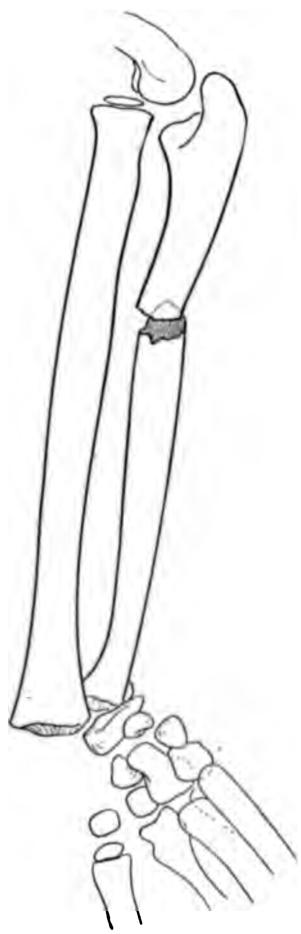


Fig. 281.—Transverse fracture of the ulnar shaft with avulsion and wide displacement of the radial epiphysis.

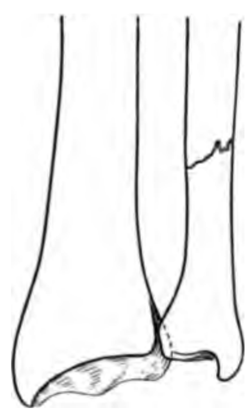


Fig. 282.—Transverse fracture of the lower part of the ulnar shaft. No separation. Cause, direct violence.

fracture and *vice versa*. The question of treatment is an important one to decide on at once. If the radial nerve is involved, it must be freed and the head of the bone resected or put back in place, and the fibrous capsule of the elbow-joint torn from the capitellum and

[1] Ann. of Surg., lvii, 266.

[2] Ibid., xlviii, 275.

ulna, is loosened and swung over the head to hold it in place. Five cases have been operated on at once, 26 after an interval of many months. The early operation with resection of the head gives the best result.

Fracture of the ulnar shaft when much displaced can usually be returned by digital pressure between the two bones. Traction has little influence on the distal fragment as long as the radius is intact. Operation is rarely if ever indicated to restore alignment, and simple reposition is sufficient. The radial flexion at the wrist (adduction) may help hold a short lower fragment in position by help of traction of the external wrist ligaments. Splints described in fracture of both bones of the forearm are used to maintain the position of the ulna.

FIG. 283.—Buckling fracture of the lower end of the radius above the epiphyseal line. Green-stick fracture of the ulna from longitudinal compression. Ulnar styloid also broken.

FIG. 284.—Healed fracture of the radius.

Rarely, a position of supination is indicated when the ulnar fragment is displaced far toward the radius, and a sling, which presses on the ulnar side of the forearm should be avoided.

Fractures of the Shaft of the Radius.—The shaft of the radius alone is broken more frequently than it was formerly thought to be. In the statistics given on page 454 it is found that the shaft or head alone was concerned 158 times out of a total of 826 fractures. Direct violence, or indirect violence of a twisting character accounts for the majority of these injuries, but indirect violence from falls on the hand, giving pressure in the longitudinal axis of the bone, causes a small proportion. The buckling fractures (see Fig. 283) are excellent examples of this mechanism.

Muscular action may also act when the hand is fixed or forcibly rotated while the muscles are acting in the opposite direction.

The plane of fracture may be of any type, according to the cause; it is commonly transverse or oblique and is rarely comminuted. Displacements vary; in a transverse fracture there may be little more than an angular change in the axis of the radius at the site of fracture, the bone ends holding apposition, because the periosteum or surrounding muscles fix them and the splint formed by the ulna is intact (Figs. 284, 285, and 286). In oblique or comminuted fracture, or transverse with displacement, the usual position is with an angularity forward and inward with a very small amount of overriding. Rotatory displacement can also occur between the two fragments

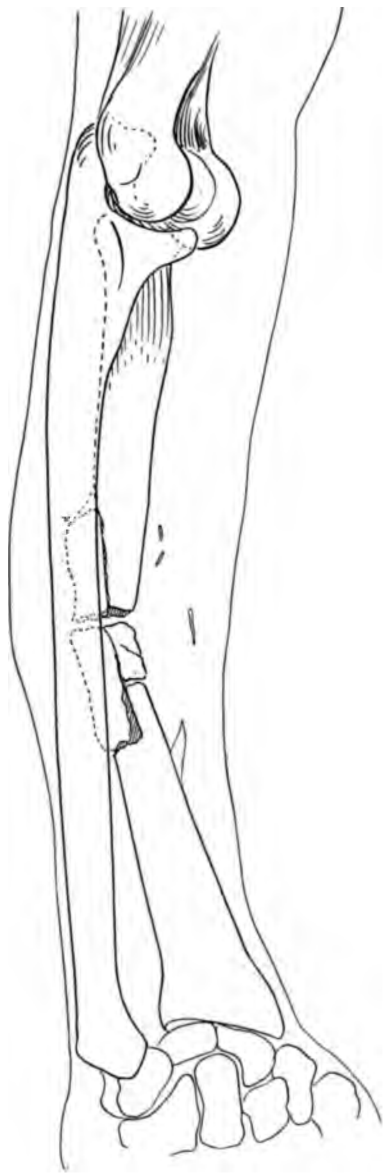


Fig. 285.—Comminuted fracture of the radius with displacement.

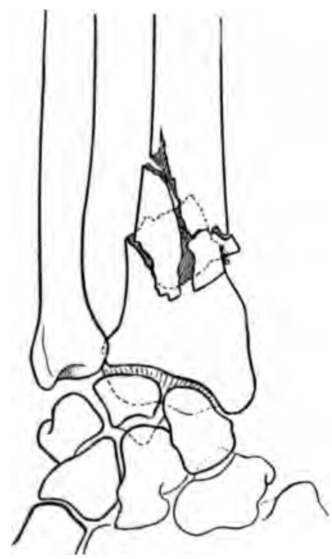


Fig. 286.—Comminuted fracture low down in the radial shaft; fragments held by periosteum.

with very little angularity or evidence in the roentgenogram. This is of importance in those fractures above the insertion of the pronator teres,

attention to which was called by Lonsdale,[1] and to which I made reference in speaking of fractures of both forearm bones. When the line of fracture is above the pronator teres muscle, the biceps tends to supinate the upper fragment and draw it forward. If union occurs with the upper fragment in this position, we should expect loss of supination of the forearm; hence in this type we dress the arm in supination. Fracture of the middle third, or just above the attachment of the pronator quadratus, is followed by the pulling of the upper fragment into outward rotation and abduction, while the pronator quadratus draws the upper end of the lower fragment toward the ulna. This must be guarded against union which will restrict the amount of

FIG. 287.—Oblique fracture of the radius with angular displacement.

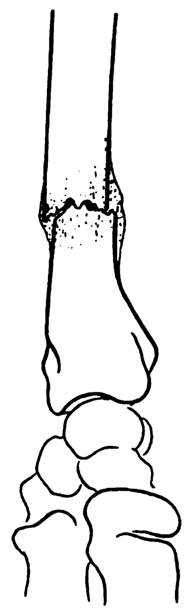


FIG. 288.—Lateral view of healed fracture of the radius.

supination, and the arm is splinted in a position of supination which gives the greatest distance between the two bones, and in addition the hand is strongly adducted so that the pull of the external lateral ligament at the wrist will hold the lower fragment away from the ulna. It is impossible to have great overriding unless the ulna is also broken or dislocated out of position at the wrist (Figs. 287 and 288).

Symptoms and Diagnosis.—Localized tenderness, an apparent angularity, loss of function in the forearm with crepitus on rotation, give ample evidence of fracture. The ulna is felt along its whole length and found uninjured. The patient's hand is grasped by

[1] London Medical Gazette, 1832, ix.

the corresponding hand of the examiner and the forearm is rotated. This reveals crepitus and the fact that the head of the radius does not rotate with the rest of the shaft, if complete fracture exists.

Treatment.—Treatment varies in accordance with the site of fracture as suggested above. When the break is above the insertion of the pronator teres, the forearm should be held in supination at right angles to the arm and a moulded plaster splint applied which envelops two-thirds of the forearm circumference, extending from the wrist to the axilla; or two moulded plaster-of-Paris splints may be used, one on either aspect of the forearm, extending well above the elbow. Manipulation and extension after the placing of the arm in supination may succeed in getting the fragments into perfect alignment.

In fracture in the middle of the bone the indications are similar to those for treatment of fracture of both bones. The position midway between pronation and supination with the forearm at a right angle is the most comfortable to the patient. Angular deformities are carefully corrected by slight pressure to bring the shaft of the radius in a straight line and a moulded plaster splint or the well-padded board splint used in both bone fractures, is applied. Fractures just above the insertion of the pronator quadratus muscle should be dressed with the arm in full supination and the hand in adduction to obtain the pull of the external wrist ligaments to hold the lower fragment out from the ulna. To accomplish this Alexander[1] has advised an internal lateral pistol splint on the forearm for holding the adduction of the hand and an anterior angular splint on the arm and forearm for holding the forearm in supination. This permits muscle relaxation in the forearm by bringing the bones into the same plane and parallel to each other. Twelve to fourteen days in this position permits bony union to start, and then the forearm can be released from its supination and gently splinted in a more comfortable and normal position. The splints should be kept on about five weeks, massage being started in the fourth week. No rotation exercises are advisable until early in the fifth week. Some deformity of an angular character is a common result, especially if the instructions as to supination are not followed. In children this may not interfere seriously with function, but in laboring adults the loss of rotation or supination causes permanent partial disability.

Lack of bony union is seldom seen. Lusk[2] records a case of fracture of both forearm bones in which the radius failed to unite because a piece of muscle lay between the ends of the fragments. He performed open operation and did a wiring which involved but one side of the bone, passing through cortex and medulla, each end of the wire being fastened to its respective fragment alone and serving to make approximation in the longitudinal axis.

[1] Ann. of Surgery, lv, 877. [2] Ibid., liv, 255.

The forearm splints should come nearly to the ends of the fingers as in the cases of fracture of both bones, to prevent the unsupported weight of the hand from favoring a recurrence of deformity.

In very muscular laboring adults, in instances where angular deformity cannot be satisfactorily reduced by manipulation or where rotatory displacement threatens loss of function, open operation with fixation by intramedullary or inlay bone graft should be done. Plating in the forearm does not seem advisable under ordinary circumstances. By slight incisions of the interosseous membrane the ends of the fragments can be sufficiently drawn out so that a small bone peg can be inserted into the medulla. In the radius the medulla need be reamed out but little. Wiring is also performed in some cases.

Colles's Fracture.—Colles first described fracture at the lower end of the radius in 1814[1] and although he confused it slightly with dislocation of the wrist, which was supposed to be much more common,

Fig. 289.—An ordinary Colles's fracture. The plane is oblique, there is slight impaction. Note the axial deformity in the wrist.

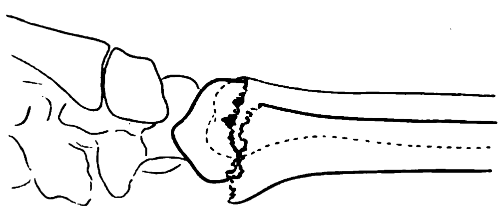


Fig. 290.—Lateral view of reversed Colles. Note the displacement upward of the distal radial fragment, producing the silver-fork deformity.

his name has been rightly applied to this injury since better observations on dislocation of fresh cases has led to definite knowledge on the subject. Roentgenograms have added to our knowledge of these fractures, and their character is well understood from the standpoint of site and displacement, but controversy still exists as to the exact mechanism of production. The plane of fracture is nearer the wrist-joint than was formerly believed, a large proportion being less than an inch from the articular surface, with an average of about one-half inch. The direction is transverse in most cases, but it may be oblique from the median side of the radius across into the joint, or it may be oblique in the anteroposterior plane (Figs. 289 and 290). Cotton[2]

[1] Edinburgh Med. and Surg. Jour., x, 182.

[2] Dislocations and Joint Fractures, 1910, p. 325; Jour. Boston Soc. Med. Sci., ii, 171; Ann. of Surg., August, 1900.

made a series of experiments bearing on the line of fracture and concluded that separation by arrachement tends to produce transverse fractures very close to the joint, but that those artificially produced were more often oblique forward and upward.

Comminution is common; generally the lower fragment suffers the most, becoming split and flattened out, mushroom fashion; or the upper fragment is split by several lines of separation, and shells of cortical bone are torn or splintered out of the diaphyseal surface.

Fig. 291.—Colles's fracture, lower fragment mushroomed into upper with little axial change.

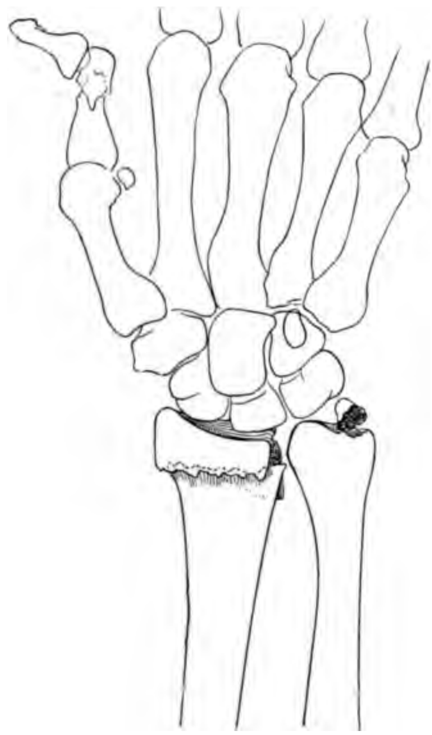


Fig. 292.—Colles's fracture with impaction and lateral displacement. The ulnar styloid has been broken off and the phalanx of the thumb also.

Displacement.—The lower fragment, loosened from the radius, may be forced into a new position as follows (Fig. 291):

(1) It may be comminuted and crushed and mushroomed onto and into the end of the diaphysis by impaction without suffering any change in its axial relations, so that merely a foreshortening of the radius and a broadening of its articular surface results (Figs. 292 and 293).

(2) There may be angular rotation of the intact or split lower fragment in either a lateral or anteroposterior plane or a combination of both. These oblique lines of separation may run:

(*a*) Upward and forward clear through the bone, without causing any forward dislocation of the lower fragment (Fig. 294).

(*b*) Upward and backward, a common variety.

(*c*) Upward and outward.

This obliquity is not sharp, seldom being greater than 30 to 35 degrees, and all forms are accompanied by the rotation upward and outward of the lower fragment, except in rare instances when the lower fragment is displaced in exactly the opposite direction, namely, downward and backward. It is this rotation which gives the appearance of outward displacement of the whole wrist (Figs. 295, 296, and 297).

The usual displacement is rotation of the lower fragment. Its articular surface is turned slightly upward, and it comes to lie on a

Fig. 293.—Nearly transverse Colles's fracture with an additional fracture plane running into the wrist-joint.

Fig. 294.—Colles's fracture with a fragment displaced from the palmar surface of the radius.

higher level than the end of the radius, being at the same time impacted into the diaphysis. The styloid process is turned upward somewhat and is found on a higher level than in the normal wrist. Avulsion or fracture of the ulnar styloid may accompany this condition (Figs. 298, 299, and 300).

(3) There may be separation through the epiphyseal line, especially in children under sixteen years, with all grades of distraction from a slight starting of the lower fragment out of position to complete displacement in accordance with the usual findings, as under (2).

No two Colles's fractures are alike. Although fresh specimens caused by the usual mechanism can be obtained, the injury seldom leads to amputation, and postmortem examination of the wrist is seldom done. If this fracture is incidental to other injuries which

cause death, the method of its cause is extraordinary violence as a fall from a great height.

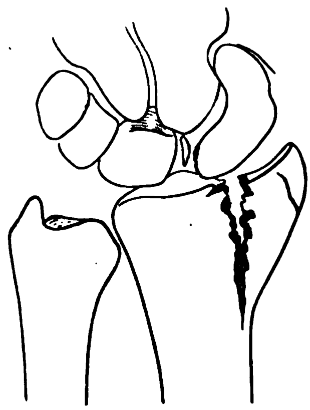


Fig. 295

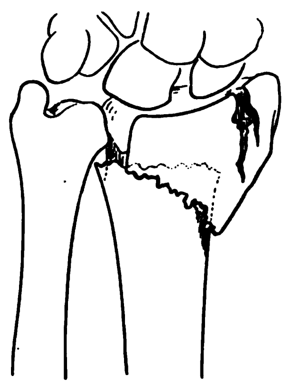


Fig. 296

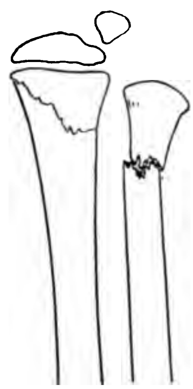


Fig. 297

Fig. 295.—Fracture of radius, longitudinal split with lateral separation. Note that a small fragment has been broken off the navicular bone.

Fig. 296.—Impacted and laterally displaced Colles's fracture with longitudinal cracks.

Fig. 297.—A confusing type of wrist fracture found in children. Complete fracture of the ulna and a complete plane through the radius without separation.

Fig. 298

Fig. 299

Fig. 300

Fig. 298.—Epiphyseal separation of both bones at the wrist in a child. Slight displacement.

Fig. 299.—Epiphyseal separation and fracture of the ulnar styloid in a fourteen-year-old boy.

Fig. 300.—Epiphyseal starting caused by fall from a swing, girl, fourteen years old. Both wrists the same.

Study of the different types of the displacement as given in the reproduction of the roentgenograms will impress the reader with the fact that posterior displacement of the lower fragment is not very marked. Tilting and comminution are common, and impaction or

driving of the lower piece into the upper fragment is the usual finding. This displacement conforms to the clinical deformity. The hump-like mass from shortening of the radial side of the wrist and the prominence into which this shortening throws the ulnar styloid with seeming deformity on the outer side are manifest, because the carpal bones

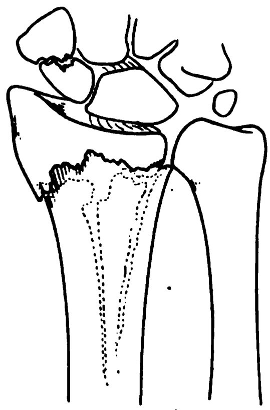


Fig. 301.—Impacted Colles with long linear planes of separation in the radius and fracture of the navicular.

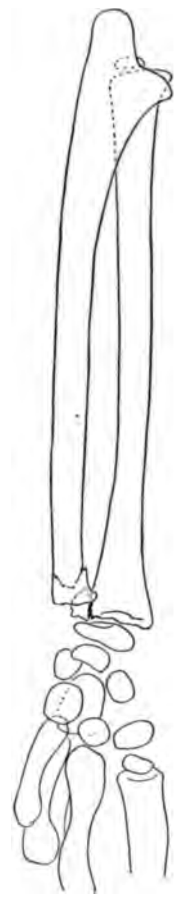


Fig. 302.—Epiphyseal separation and fracture of the inner margin of the radius with slightly impacted fracture of the lower end of the ulna in a child. Note the upward displacement of the radial epiphysis.

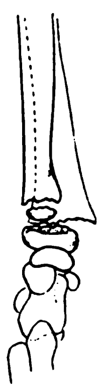


Fig. 303.—A lateral view of an epiphyseal separation of both bones at the wrist. Note the upward displacement of the lower radial fragment.

maintain their articular line and relation to the forced-up articular surface of the radius.

The accompanying pathology is as follows: The wrist ligaments are seldom torn completely but may be lacerated in Colles's fracture. From the shortening of the radial side of the wrist the external lateral

ligament attached to the ulnar styloid may be torn off, or its angle of pull changed, or it may wrench off the end of the styloid process, maintaining its own fibers intact. This last condition appeared in 15 out of 54 cases in 1914; fracture of the carpal navicular accompanied 1 case (Figs. 301, 302, 303, and 304). The radio-ulnar ligament is torn in some cases sufficiently to permit some upward dislocation of the head of the ulna, which becomes therefore more prominent than it would be from the radial damage alone (Fig. 305). Hemorrhage into the tissues from the fracture site does not occur early unless the periosteum is torn open, otherwise a subperiosteal hematoma slowly forms, which greatly increases the seeming deformity. Later evidence of hemorrhage along the interosseous ligament as far as the elbow is

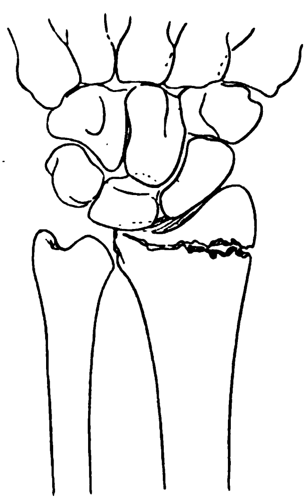


Fig. 304.—A back-fire injury from an automobile. The plane of fracture tends to select the epiphyseal line.

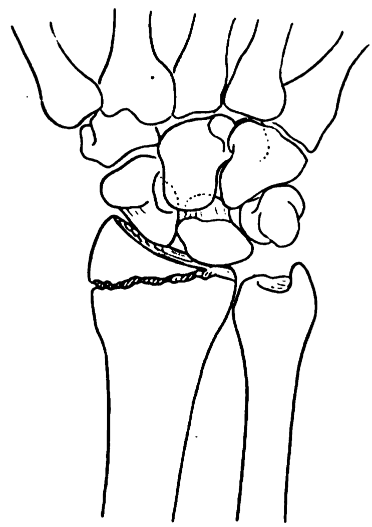


Fig. 305.—A similar injury from a fall. The palmar side of the bone alone seems separated.

noted in the ecchymoses which appear on the surface. These may also spread down into the hand. Blood is seldom effused into the tendon sheaths crossing the wrist; a serous effusion may slightly distend them but true hemorrhage into them is very rare, as it takes place alongside and outside. Resulting stiffness in the fingers and wrist is not caused so much by damage of the tendons or their sheaths from the trauma as it is by shortening of the muscles and the peri-synovial structures from long immobilization and disuse and incomplete reduction of bone fragments. Forcible effort to break up this stiffness may lead to reformation of adhesions and make the result worse. Open Colles's fractures are almost unknown. In them the upper end of the radius may be driven out of the soft parts, or the dislocated head of the ulna may come through the skin, sometimes

tearing the median nerve. Nerve injury or pressure is a rare complication. The median nerve has been reported as showing evidence of delayed injury.[1] It is sometimes stretched over the ulnar head. Periosteal stripping and laceration are common, and in old healed fractures with posterior displacement the stripping of the periosteum from the shaft causes callus to be deposited, so that a large bony mass is formed which enhances the deformity. Pieces of detached bone from the styloids may lie free in the wrist and never become attached to the parent bone. Movements and the play of tendons about these fragments result in their developing into sesamoids (see Figs. 306 and 307). The triangular fibrocartilage may also be torn. When this fracture heals unreduced, thickening of the wrist capsule, inhibition of motion, and loss of power in the hand and fingers follows.

Fig. 306.—Old fracture of ulnar styloid. The fragment never became united and has formed a sesamoid bone.

Fig. 307.—Formation of multiple sesamoid after wrist fracture.

In a young person time will overcome much of this disability, but in elderly people the prognosis for complete recovery is bad even with further treatment looking toward a better reposition of the fragments. The impaction of the lower fragment into the diaphysis causes some bone absorption if it is not reduced at once, and even in early reduction the cancellous material may have been crushed and shortened, so that full length and exact original conformity of the bone can never be restored.

Epiphyseal separations, if replaced, often lead to no permanent interference with growth, but on the other hand, an unfavorable result may follow. A case was reported by Andrews[2] and also by Stimson. Waechter[3] cites an instance in an eleven-year-old boy whose parents

[1] Blecher, Deutsch. Ztschr. f. Chir., xciii, 34.
[2] Ann. of Surg., xxxv.
[3] Ibid., xlviii, 115.

noticed a gradual adduction of the hand and projection of the ulna two years after he had suffered a Colles's fracture which had been properly reduced. A study of the roentgenogram of this case shows that the epiphysis had become bony and had probably therefore lost its growing function. Bruns found 25 cases of retarded growth in the radius in 81 instances of different epiphyseal separations,[1] and Hutchinson has also recorded cases of similar radial deformity.[2] I have 5 cases under observation at this time, some of them five years since fracture; 1 of them was operated on for deformity and none have yet developed any interference with growth.

Causes.—Colles's fracture results from one's falling on the outstretched and hyperextended hand, generally while walking, although it may follow falls from a greater height. In adults and elderly people, trips on rugs, uneven ground, overbalancing on wet or slippery walks which result in falls cause the fracture. There has been much controversy as to the exact mechanism of the usual type of displacement, and the methods of application of the force can be expressed under three headings:

1. Splitting or crushing by force transmitted from the carpal bones.
2. Radius yielding at a weak point at or above the epiphyseal area when the lines of force of the trauma break up.
3. Cross strain exerted at the insertion of the capsular ligaments in the juxta-epiphyseal area on the lower end of the bone.

In another place[3] attention has been called to the mechanism of sprains and fractures at the lower end of the radius and the author believes that the third heading demands more recognition in the mechanism in most cases than it has ever had. If the force is transmitted directly through the carpal bones it is odd that these bones are so seldom damaged, granting their ability to take up pressure stress on account of their number and arrangement. The breaking up of the causative force into its component parts has less to do with the tilting and displacement backward of the lower fragment than the pulling stress of the tense capsular ligament on this portion of the radius in response to the tension from the attachment below to the carpal bones. Sir Astley Cooper's experiments, in 1833, and Bounchet's, in 1834, showed that transverse fracture at the lower end of the radius could be produced by this ligamentous pull (the author does not believe it is a true avulsion except in those cases where a small lip on the surface of the bone is pulled out) (Fig. 308), but the experiments also produced rupture of the anterior ligament and dislocation or fracture of the carpal bones. Consequently, such an authority as Stimson, while admitting that the fracture may be caused by this means, does not consider it the usual mechanism because of those other injuries which happened in the cadaver about as often as fracture of the radius.

[1] Langenbeck's Arch., Berlin, 1881–2.
[2] Arch. Surg., London, 1892–93.
[3] Speed, Surg., Gynec. and Obst., August, 1913.

There has been left out of consideration the fact that those who sustain this fracture are live people whose strongest instinct is self-preservation. As they feel themselves falling they unconsciously throw out a saving hand and receive the impact on the palm with the wrist as stiff and rigid as it lies in the power of the many tendons and ligaments encasing the joint to render it. Some force must be carried to the end of the radius by the carpal bones, but the cartilage in the wrist-joint and the separation and distribution of the numerous wrist bones take up some of this force in a cushion-like manner, and the greatest burden is borne by the stronger-than-bone ligaments, the pull of which takes place at their points of insertion in the radius. If the fall is not so well guarded or the individual is old and has rarefied bones, we expect the direct carpal pressure to cause more damage, as evidenced by great comminution, more impaction or injury of the carpal bones. What in one case will give merely a sprain with ligamentous damage, in another will cause epiphyseal or sprain fracture of the styloid process, with little displacement and no comminution. This cross strain, force of which is received by the palm as the hand is extended, is exerted just above the end of the bone by the anterior and lateral ligament. As the hand is bent back the ligament is put under extraordinary stress, and the lower fragment is broken. In the so-called chauffeur's fracture a like mechanism, caused by the sudden forcible back jerk of the crank handle, puts this unexpected and powerful strain on the lower end of the radius *when the ligament is tense* with the exertion of cranking, causing a transverse or diagonal fracture.

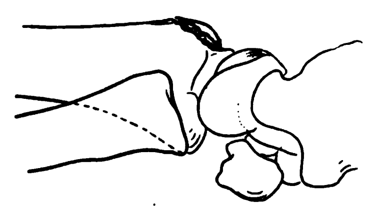


Fig. 308.—Avulsion of a portion of the dorsal lip of the radius by ligamentous pull.

If one takes first a juxta-epiphyseal strain which gives but slight evidence in the skiagram of the pulling-out strain caused by the trauma; follows through with more pronounced cases, first of sprain fracture involving a corner of the styloid process, then the more extensive injury cracking the bone nearly across the diameter of the lower end; and finally an impaction of the two fragments after this cracking across, with little if any silver-fork deformity or anteroposterior displacement, one finds that the fracture leads on to an ordinary Colles in accordance with the three methods of mechanism mentioned.

Recapitulated, the mechanism seems to follow in this order: fall on hand pronated and probably abducted, tearing stress of lateral and anterior ligament which is tougher than the bone to which it is attached, tearing or splitting off of corners or whole diameter of the radius, continuation of force driving lower fragment up into shaft by transmission of line of force from wrist bones, and finally comminution by a breaking up of the line of force as trauma ceases.

Symptoms and Diagnosis.—The most striking symptom is a sign, the deformity. The wrist bones seem dislocated backward, and a hump-like mass takes the place of the normal straight line which can be drawn from the forearm across the wrist to the base of the fingers with the hand in extension. In the normal wrist a straight edge laid on the forearm with the hand in extension touches at all points. With the deformity following Colles's fracture this test can not be applied because of the so-called "silver-fork" curve at the site of fracture, the distal portion of the radius having been displaced backward. There is also pain in the wrist, tenderness on pressure over the break and frequently over the ulnar styloid, and inability to grasp with the usual hand grip. Swelling follows and increases the deformity on the dorsum of the wrist, while on the palmar surface there appears also a bulging from the edema and hemorrhage and the projection of the upper fragment of the radius. The silver-fork appearance, as has been proved by roentgenogram, arises not so much from the actual displacement of the lower fragment, as from the swelling in the soft parts and the shortening of the radial side of the wrist with the tilting up of the joint surface of the radius. The ulnar styloid appears more prominent, and on comparison of the sound and injured wrists it is noted that the styloid tip of the broken radius has been pushed up more nearly on a level with the ulnar styloid. In the well wrist it normally lies on a level some three-eighths inch lower.

Crepitus may be entirely absent, as also abnormal motion, if impaction is present. To obtain these signs the examiner grasps the shaft of the radius in one hand and the lower end in the fingers of the other and by movement in opposite directions may obtain both findings at once. It is sufficient to find that this test elicits great pain. Pencil pressure down the shaft of the radius usually discovers the exact point of fracture through the pain produced, and attempts to hyperextend the hand cause pain above the end of the radius. Flexion is usually much limited on account of the displacement, and the grasping power of the hand is reduced to nothing.

Sprain fractures or linear cracks with no apparent deformity may give all the above-mentioned findings except the silver-fork appearance (Figs. 309 and 310). The finding of a recurring point of extreme tenderness on the lower half-inch of the radius with the history of sufficient trauma leads to diagnosis of these lesser fractures. In doubtful cases of no legal importance a few days' wait will determine whether the injury is sprain or fracture, but in the meantime every case should be treated as fracture, and the Roentgen examination should be made at once if there is liability. After a few days' rest a sprain will be much less painful, function will be returning or increased beyond that of the first examination, whereas in fracture even a mere crack will give the recurrent extreme tenderness and great delay in functional return.

Colles's fracture must also be differentiated from fractures of both

bones near their lower end. *Contusion* and *subperiosteal hemorrhage* of the bones at the wrist which do not involve a change in the posi-

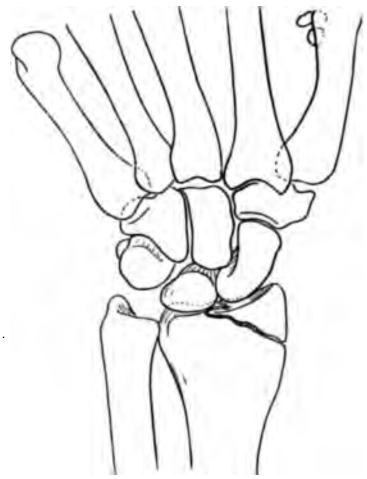


Fig. 309.—Sprain fracture of lower end of radius. Note the involvement of the articular surface.

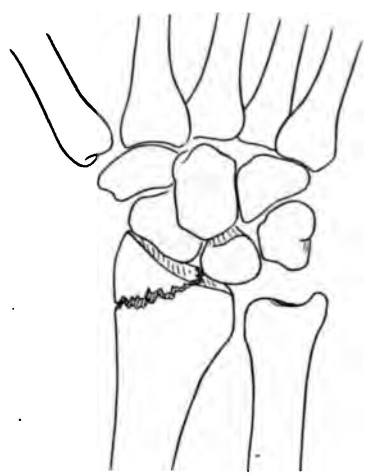


Fig. 310.—Chauffeur's fracture of lower end of radius with some displacement.

tion of the styloids are rare and have a swelling below the point of silver-fork deformity. Dislocation of the wrist backward likewise has a deformity lower than a Colles's fracture, and the two styloids are in normal position.

Prognosis.—Bony union is almost invariable, in many cases too prompt, if the patient has not been seen at the time of accident and seeks advice after a few weeks for persistent loss of function in the hand. After a month the deformity is marked and it is very difficult to break up the union. Permanent deformity of varying degree exists in most cases except in youths, who may outgrow it readily. In adults, with the best reduction possible, some shortening of the radius or tilting of the lower fragment, thickening of the wrist and prominence of the ulnar styloid can be expected (Fig. 311). These results are caused by comminution and difficulty of reducing the bone. Function is frequently very good when the deformity is quite apparent. After a year, if use is persisted in, the function should be as good as it will become, and although flexion may be limited on account of the tilting, use is painless and is very satisfactory. Much depends on the manner of reduction and the after-treatment. Early mobilization with gentle massage and wrist

Fig. 311. — Healed Colles's fracture. The silver-fork deformity persists. Note how the radial joint surface points downward.

motions avoid swollen and stiffened joints in the fingers, which are largely the result of splint pressure. The use of the Roentgen rays helps to call attention to accompanying fractures and dislocations of the carpus. These should be treated early and disability charged to them and not to Colles's fracture if the wrist injuries are overlooked.

Treatment.—As a preliminary step to treatment the surgeon should study the injury, comparing with the sound wrist to satisfy himself on the following points: comminution of the lower fragment as evidenced by the broadening, the degree of impaction ascertained by the apparent shortening of the radius and the inability to move the lower fragment by manipulation. The amount of backward displacement and rotation of the lower fragment upward or outward should also be determined. Women, children, and elderly people, as well as robust adults with much displacement and muscle spasm should be treated while under a light anesthesia. Gas is sufficient in most cases to ease pain and relax muscles, or the ether rausch is very efficient.

Treatment consists in reduction. In the case of elderly persons or children under anesthesia, by grasping the wrist in both hands, and pressing the thumbs down on the lower fragment and up on the upper fragment one may quickly accomplish reduction. Impaction, stronger bones, or bulky muscles frequently demand more force and interlocking of the fragments. The surgeon grasps the patient's hand or wrist in his right hand and hyperextends it in an attempt to unlock the overriding and impacted lower fragment. Repeated vigorous motions of flexion and extension are necessary frequently for the gaining of the freedom of the lower fragment. If the rotation and displacement are backward and outward with impaction, a motion of circumduction of the hand in a wide arc usually frees the bone. When this is attained, the hand is brought into sharp flexion, while traction is made in the long axis, aided by pressure downward on the lower fragment. Lateral deviation is corrected by this same maneuver, aided by direct pressure and adduction, and the hand is allowed to lie lax while the wrist is examined for persisting deformity. Persisting impaction which resists this force can be broken up by the operator grasping the wrist while it rests on his knee and rocking the fragments forcibly with the hands.

Reduction must bring the displaced and rotated fragment down into place. *When it does, the hand will lie laxly in a position of flexion if the forearm alone is supported, and the silver-fork deformity will have disappeared.* Overreduction, forcing the lower fragment down below the line of the upper fragment and reversing the displacement, must be avoided. When reduced there is no tendency for the deformity to recur, and the styloids should have regained a normal relative height, the radial again being lower.

The indication for splinting is then simple. The old pistol splints are of no value, as they attempted to hold the fragment in place, or

to correct radial shortening by abducting the hand and using the pull exerted by the internal lateral wrist ligament. That fallacy has been fully exposed. No splint holding the hand in abduction will prevent radial shortening after the bone has been crushed, and the value of this position to maintain reduction was greatly overestimated and led to longer disability from the fingers being held in a cramped position.

The easiest splint to use is one of moulded plaster extending on the forearm from the elbow to the base of the fingers with a pad over the back of the hand and also a pad over the lower end of the upper fragment and the ulna in front (palmar surface). This is applied and bandaged on, the hand being held in a position of slight flexion with fingers free to move. This splint will make no constriction and is advisable for a few days to give the patient a feeling of security and to permit swelling to subside. It can be carried by a handkerchief sling about the neck, or, if the patient wishes to avoid attracting attention, no sling at all is needed, and the arm can be allowed to hang or be tucked into the coat when at business. Some surgeons rely so much on the reduction that they use no splint at all, merely strapping the wrist about with a broad band of adhesive. I believe the rigid splint does no harm when worn a short time and is advisable for the reasons give above. Wooden splints may be used. They should be broad, the dorsal splint extending from the elbow to the wrist, the palmar splint starting at the same level and extending to the base of the fingers. These are thoroughly padded, as for the moulded plaster splint, and are strapped together by adhesive. Piano or saddler's felt is better material for these pads than cotton, as it has more elasticity and does not get lumpy and out of place. Pressure of the splint and pads must be avoided over the dorsum of the upper radial fragment and the ulna and over the thenar eminence.

The hand is inspected within a few hours for swelling, cyanosis, feeling of numbness and pain from pressure. As a rule the patient feels relief from most of his pain as soon as reduction is made, and with the light plaster splint feels comfortable in an hour or two. If any particular point of pain is complained of, the splint should be removed at once and pads and reduction investigated.

After-treatment.—On the second or third day the splint is removed and the hand and forearm is lightly massaged, passive motion being given to the wrist. This is continued daily with a longer massage and instruction to the patient to exercise the fingers much of the time. After eight or nine days the splint is removed during the day and put on at night, and after fourteen days no splint is needed. The wrist is then strapped or bandaged snugly, and active motions are advised. Union is firm, and the wrist is in good condition in one month, without finger swelling or stiffness except that incident to the immediate result of the trauma. A leather wrist strap can be worn after active use is begun until the ligaments regain tone.

Pain and weakness in the ulnar side may be a persisting symptom. This is caused by an imperfect repair of the external wrist ligaments

or a slight dislocation of the hand, and strapping with rest and time will improve the result. If limitation in flexion of the wrist is found after several weeks while extension or hyperextension is greater than normal, the effect probably results from a change in the plane of the wrist-joint through tilting of the lower fragment. The same explanation is offered for a limited adduction or a too great abduction. These are favored by rotation of the lower fragment and the articular plane rather than by any great amount of broadening of the wrist or separation of the two bones at the lower end. Reduction may be as perfect as can be accomplished with no return of the gross deformity, yet in six or eight weeks the patient will come complaining of poor function, and the surgeon will feel that possibly he is at fault. This is not so; considering the character and size of the wrist-joint, the crushing of the radius, and other points, such as backward displacement and rotation, outward rotation of the lower fragment and radial shortening, if the silver-fork deformity is obliterated and the lower fragment is returned into the best position obtainable at the time of reduction, no fears should be felt for considerable functional return in due time. After satisfactory treatment, it is usual to find a slight prominence and forward displacement of the ulna and some flattening of the lower radial arch as an end-result. More displeasing deformities result in cases caused by extreme violence when the fragments are badly comminuted and the splints do not hold firmly, or when in senile bones the radius is crushed so that on reduction of the lower fragment a gap persists between it and the shaft on the outer surface. If the ulna has suffered marked displacement, the deformity of its lower end may be unpleasant and even increased if use is permitted before strong ligamentous healing has followed. This healing may be greatly delayed because of poor personal reparative power.

The indications for operative treatment are narrow. Practically every fresh case can be reduced by manipulation, and I have never operated on one. If a case is neglected or not reduced and after a few weeks' manipulation fails to establish a satisfactory position of the lower fragment, reduction by open operation should be done. Uncorrected epiphyseal separations or fractures in youths, unsightly deformities or restricted function in adults, are also good grounds for open replacement. Much can be promised as to decrease in deformity, but the matter of function is not so happy of solution.

In younger people a lateral incision over the fracture, with retraction of the tendons, exposes the bone through a two-inch incision. A sharp chisel, equalling the diameter of the bone, is then driven through the site of fracture, and by manipulation the deformity is corrected so that the lower fragment lies in good position. In adults, especially long-standing cases, with callus formation beneath the stripped-up periosteum, a dorsal incision is made. All tendons are retracted, and after the periosteum is reflected from the radius the excess callus is chiseled away, the bone cut through, and the lower fragment replaced. Closure of the periosteum follows.

Deformities of the lower end of the ulna rarely demand operative treatment. Efforts to strengthen or suture the lateral ligament too often end in failure, and a loosely displaced fragment of styloid process does not demand removal unless it interferes with joint motion or causes pain. If the lower end of the ulna has great displacement, there may be indication to resect it. (See Madelung's deformity.)

Other fractures at the wrist are: *Reversed Colles's fracture*, that is, the usual displacement of the lower fragment is downward toward the palm, opposite to an ordinary Colles. These fractures are uncommon and are due either to direct violence on the dorsum of the wrist, which drives the lower fragment down, or to falls on the back of the hand. In these cases flexion is greater than normal, extension is limited, and the relation of the styloid processes may be the same as in a Colles. Above the wrist-joint the shaft of the bone causes a prominence, because the lower fragment is depressed, and the deformity may be mistaken for the silver-fork variety. On the palmar side there is a sharp projection caused by the pushing out toward the palm of the lower fragment. The other findings are like those of a Colles in regard to impaction, shortening, etc. Reduction is accomplished by manipulation as in the Colles, effort being directed toward raising the fragment up into its normal position in line with the radial axis. It is possible that too violent attempts at reduction of a Colles's fracture might force the lower fragment down into this opposite position.

Fractures of both bones at the wrist, also uncommon, give the same findings as a Colles, with a lower and more flail-like wrist. This injury is to be diagnosed by the finding of the plane of fracture in the ulna and is differentiated from dislocation of the wrist through the fact that the styloid processes bear a normal relation to the wrist bones. Treatment is that given for Colles's fracture, and great care must be observed to keep the hand in line of the forearm axis. Palmar and dorsal splints on the forearm, extending to the finger tips, are necessary to maintain immobility. Disability is three to four months.

Barton's fracture, as described by him,[1] consisted in a breaking off of the posterior tip of the articular end of the radius at the wrist. This fracture was supposed to be frequent, particularly in wrist dislocations, as a small fragment of the radius was pulled out by the ligaments and carried away by them as they lost their hold on the radius. These fractures we know now are fairly common, they accompany sprains of the wrist, and the fragment is seldom widely displaced (see Fig. 308). Diagnosis is made by a localized point of tenderness and circumscribed swelling, which persist. They must be differentiated from injuries of the scaphoid and semilunar bones (which see).

Fractures of the radial and ulnar styloid processes are common (Figs. 312, 313, and 314). Many of them involving the radius are the Chauffeur's fracture, caused by a sudden back jerk from back firing of a

[1] Med. Exam., 1838, p. 365.

same type of fracture, which is so much like Colles's, is caused by falls and direct violence.

Treatment is rest on a palmar splint for two or three weeks. Isolated fracture of the ulnar styloid is also found. It is caused by direct violence or fall on the adducted hand. Fracture of this process also accompanies injuries of the carpus. The surgeon may be able to palpate the loosened fragment or find pain in the styloid region. I have seen several cases where the process was broken and bent down with no separation, uniting with the head in the new position. Some pain and permanent stiffness result. Other cases of separation probably never unite (see Fig. 315). The small fragment becomes sesamoid in character. This I have also observed once in a fracture of the radial styloid.

Treatment consists in holding the hand in abduction on a palmar splint. If no reduction can be obtained and the displaced fragment gives pain or interferes with joint motion, it must be excised.

CHAPTER XVIII.

DISLOCATIONS OF THE ELBOW.

In the discussion of fractures of the humerus at the elbow the practical points of the anatomy of the elbow have been reviewed. One must recall that the external condyle of the humerus articulates with the head of the radius by means of the capitellum and that the lips of the trochlea with the help of the lateral ligaments, guard and direct the movements between the ulna and the humerus. The joint capsule is attached above the coronoid and olecranon fossæ in such a manner that it blends with the periosteum, while on the inner side it is attached to the prominent lip of the trochlea, and the internal condyle lies without the joint. The location of the points of the elbow are also important; with the arm in full extension, the points of the external and internal condyles and olecranon assume almost a straight line, the olecranon lying slightly higher, while in flexion the olecranon point forms almost an equilateral triangle with the other two, lying over an inch below and between them slightly nearer the internal condyle. These points can be made out even in the presence of great swelling, and, supplemented by palpation of the head of the radius when the forearm is rotated, give definite information of the condition of the elbow. Every elbow examined must be compared with the opposite one that individual peculiarities may be noted. The olecranon can be identified by palpation of the ulna in the forearm up to the joint and the sharp projecting point of the internal condyle, and the ulnar nerve can be recognized by being rolled under the finger. Edema and swelling about the joint may be reduced by gentle massage sufficiently to permit diagnostic examination, but in some cases the arm must be put at rest in a sling with cold applications until the swelling subsides.

Frequency.—In seven and a half years at the Cook County Hospital the records show an admission of 796 cases of dislocation, of which 53 were of the elbow. In the last eighteen months of this period there were 16 cases, 13 in males, 3 in females—4 being in children. This bears out other statistics, namely, those of Krönlein, who is quoted by Stimson in statistics covering 109 cases. Males predominate at a ratio of 4 to 1, and children often suffer the luxation, because their arms are more frequently hyperextended in falls. Adults in the third and fourth decade are more likely to fall with the arm in slight flexion held by the strong muscles, so that the violence is carried indirectly to the shoulder and results in shoulder dislocation or fractures of the clavicle. Of the 16 cases mentioned, 9 were reduced

promptly, 2 refused treatment, 1 refused operative treatment, 1 child suffered gangrene and amputation, and 3 cases were operated on.

Types of Elbow Dislocations.—Any elaborate classification of elbow luxations is confusing for practical purposes. The following simple ones, depending on the involvement of one or both bones of the forearm, is convenient:

Dislocation of both bones backward, lateral, forward, and divergent.

Dislocation of the radius alone.

Dislocation of the ulna alone.

All types of elbow dislocation may vary in extent, according to the strength of the primary violence and the secondary position assumed when the violence continues to act after the joint is displaced. The causes of these luxations are the same, whether they are complete or incomplete, and we shall consider them all together, making special reference to such types only as are recognized clinical entities.

BACKWARD DISLOCATION OF BOTH FOREARM BONES.

This displacement is the usual one at the elbow and is caused by falls on the outstretched hand with extension and abduction of the forearm. Both adults and children are subject to this displacement, the ultimate position of the luxated bones depending on what direction the force pushes them in and whether the body weight twists the forearm as the patient falls—the hand remaining fixed. Direct violence applied above the elbow causes fracture of the humerus, and applied on the forearm in blows and torsion strains may rarely cause elbow dislocation. The mechanism is one of leverage. Hyperextension with or without abduction causes the olecranon point to impinge against the humerus. This point becomes the fulcrum of the lever, the power is the weight of the falling body above, and the weight is the resistance of the anterior and lateral ligaments of the joint, which become tense and are strained to the breaking point, the forearm bones slipping out posteriorly into dislocation. If the forearm is in some abduction with the hyperextension, we should expect the first and greatest tearing evidence to be manifested over the internal condyle, the capsule and ligament rupture starting there. It often happens that the tip of the condyle is torn off together with the insertion of the flexor muscles of the forearm. Experimental work on the cadaver imitating falls on the outstretched hand verifies the tearing of the anterior ligament on the internal side when the hand is supinated. The ligament and capsule give at this point, the elbow-joint is depressed inward, and the lower end of the humerus is shoved down in front of the head of the radius and the coronoid of the ulna until the luxation is accomplished.

Pathology.—The tear in the anterior ligament has been described as always occurring high up near its insertion on the humerus, the line of separation running inward through the internal lateral ligament in the usual position of abduction. The cases of unreduced

posterior dislocation of the forearm which I have operated on do not verify this statement, as I find that the anterior position of the capsule is torn low enough down to leave a small flap which hangs down over the articular surface of the joint and by its adherence and interposition offers a real obstacle to reduction. On theoretical grounds one would expect the ligament to tear at a lower level than near the point of insertion into the humerus, because the point of greatest stress is near the radius and ulna, and the insertion of the ligament into the periosteum of the humerus is its strongest point. The internal lateral

Fig. 316. — Fresh dislocation of the elbow backward, the coronoid lying under the olecranon fossa.

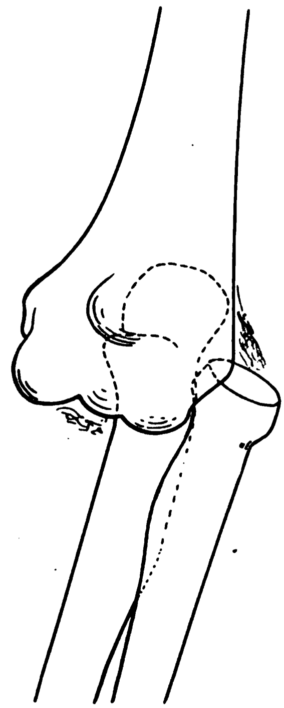


Fig. 317.—Anteroposterior view of an old dislocation backward, the radial head lying beneath the external condyle.

ligament is similarly torn; the external lateral ligament may be intact or stripped up from the humerus, lifting the periosteum. The orbicular ligament about the head of the radius is intact.

The displacement of bone is not uniform in all cases. Both bones may be slipped completely and directly backward, the coronoid lying under the olecranon fossa or against the edge of the trochlea (Fig. 316). The greater the bone displacement, the greater the capsular and ligamentous tear. When abduction has had a prominent part in the luxation, the radial head may remain in partial contact with the capitellum, while the coronoid rests against the under surface of

the trochlea, but usually both bones are displaced well backward, so that the head of the radius lies beneath the external condyle (Fig. 317). Rarely the coronoid comes to lie against the posterior surface of the external epicondyle and the radial head lies on the outer side. The long axis of the forearm consequently varies within 15 degrees on either side of the normal axis in pure backward dislocation, depending on the conditions outlined above. (See Outward and Inward Lateral Dislocation.)

Complications.—Bone complications, particularly fracture, involve the humeral condyles and the tip of the olecranon, which is mashed by the force delivered from the humerus above or is pulled out by

Fig. 318.—Backward dislocation of the elbow with epiphyseal separation and fracture of the internal condyle of the humerus.

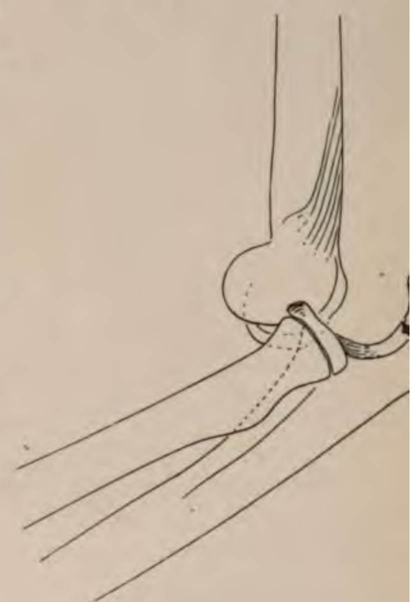


Fig. 319.—Backward dislocation of the elbow with epiphyseal separation of the olecranon.

the attached ligament, the periosteum stripping off the bone surface (Figs. 318 and 319). The coronoid of the ulna may be cracked or split off completely, generally with little displacement. Frequently injury of the radial head is found. It may be cracked longitudinally or a chip may be broken off its inner side as the bone is displaced. Extreme violence acting before dislocation is complete may break the neck of the radius and the ulna near its upper end (Fig. 320). Rarely the lower end of the humerus is driven through the soft parts of the front of the elbow, or the brachial artery is ruptured. I have seen one case of closed elbow dislocation with arterial damage which led to gangrene and amputation. Reducible cases seldom lead to

involvement of nerves. The ulnar is spared unless there is condylar fracture. Dislocation of the ulnar nerve from its bed may accompany the elbow luxation and be independent of fracture of the internal condyle. Cobb[1] found 2 cases in nine years at the Massachusetts General Hospital. There are now on record 23 cases which have been operated on after dislocation of this nerve, the only indication being pain and paralytic symptoms, the nerve dislocation itself not constituting any reason for open operation. The median and radial may be involved, especially in old irreduced dislocations which produce much cicatricial tissue and callus formation beneath stripped-up periosteum. Open dislocations at the elbow are rare and usually accompany severe injuries and fractures of the same arm.

FIG. 320.—Backward dislocation of the elbow with fracture of the lower end of the humerus.

General Symptoms and Signs of Dislocation of Both Bones at the Elbow.—In the backward and lateral dislocations the forearm is usually in a position of partial flexion, forming an angle approximating 135 degrees with the arm. Rotation is impossible and when actively attempted is very painful. Looked at from in front the forearm seems shortened, because the lower end of the humerus sticks forward, and bulging out the flexor muscles attached to the condyles broadens the forearm. A side or back view gives almost the opposite appearance, because the olecranon is raised above its normal level, the arm consequently seems shortened, and the forearm appears to have a normal length. There is thickening antero-posteriorly. The direction of the axis of the forearm may vary in or out within 15 degrees from the normal axis, and the hand may rest in any position from full pronation to extreme supination. The elbow-joint is enlarged, and if the patient is not seen until several hours after the accident the swelling may be great enough to obliterate all bony points. The forearm may be flexed a few degrees by passive motion, but never as far as a right angle and only with pain. The elbow has an abnormal lateral mobility, and when the forearm is flexed the olecranon may be seen to move beneath the skin on the back of the arm. There is muscle spasm and in some cases a pseudocrepitus caused by the rubbing of the forearm bones against the trochlear edge. Occasionally the forearm is in complete extension.

Examination seeks to determine the position of the bony points

[1] Ann. of Surg., xlviii, 409.

previously mentioned. The points of the condyles and the olecranon are sought by palpation. The olecranon is found much higher than its normal level compared to the corresponding joint, with a depression in the triceps tendon above it. The head of the radius may be seen or felt as a rounding projection behind the external condyle. This projection one can recognize at the head, or the head plus a portion of the broken-off external condyle, by pressing against it with the fingers of one hand while the other hand rotates the forearm. If it moves, it is probably the radial head; if it is immobile, it is certainly the external condyle which has not been fractured. The internal epicondyle and ulnar nerve are also recognized by palpation. In front the surgeon may be able to identify the trochlear surface of the humerus by both sight and touch, not so easily in fat and muscular patients as in thin ones.

FIG. 321.—Backward dislocation of the elbow and fracture of the radius.

The diagnosis rests on the findings described and the lack of crepitus and shortening of the arm or forearm. To differentiate small fractures of the olecranon and radial head is difficult by whatever means of external examination. Great tenderness over the radial head when the forearm is rotated may permit a diagnosis of fracture, particularly after reduction. However, one sees many cases overlooked and many diagnosed which are unproved by the roentgenogram. For that reason roentgenograms in both planes should be taken both before and after reduction of elbow dislocations, because bone injury of the coronoid and radial head may not appear in the first set of pictures (Fig. 321).

I find it almost impossible to diagnose accompanying injury of the condyles without the help of the roentgenogram, and it seems that fractures of them are less common than tearing fractures of the olecranon, stripping of the humeral periosteum, and injury to the radial head. In children the differentiation lies between fracture just above

the joint (dicondylar) and backward dislocation. In fracture the bony points maintain normal relation, and the deformity exists above the joint. T-fractures into the joint in adults are also difficult to differentiate, unless the loosened condyles can be grasped and manipulated independently to obtain crepitus and also motion.

Prognosis.—The prognosis of fresh dislocations promptly reduced is good, unless there has been serious vascular or nerve injury. These complications are rare. Pressure on the radial or median, which gives numbness or tingling hyperesthesias, usually improves promptly after reduction. Fracture complications or the formation of callus beneath stripped periosteum may hinder the development of functional activity. After-treatment has much to do with functional return.

The elbow-joint has a great tendency to produce irregular masses of callus not only connected with its bony points but also in the surrounding muscle. The brachialis anticus and the triceps are the usual muscles involved in a post-traumatic myositis ossificans. Previous reference to this condition has been made in the chapter on the Pathology of Fracture. The origin of new bone formation is not always to be traced to periosteum. It may be a metaplasia of the connective tissue of the capsule or the intermuscular septa or may originate from osteoblastic cells which have wandered from the torn periosteum and proliferated. Lehmann[1] collected 37 cases of post-traumatic ossification at the elbow-joint occurring in a period of eight years. Posterior dislocation had occurred in 19 cases. All showed new bone formation in the two muscles mentioned, part of it being of intramuscular formation. Complete rest for at least two weeks after reduction of dislocation has the greatest influence in reducing this par- and periosteal callus. We also know that in accordance with Wolff's law these masses slowly absorb and disappear, if irritation is not continued. Consequently a long immobilization of the arm in a flexed position will often cause their disappearance. Operative removal should be the last step in treatment after conservative methods have failed.

When a luxation remains unreduced because of non-recognition or obstacles to reduction, it becomes impossible to effect reduction after a period of from four to six weeks on account of the cicatricial and callus changes which develop about the trochlear and sigmoid surfaces and beneath the stripped periosteum. (See Old Elbow Dislocations.) If the patient has a tendency to osteo-arthritis the surgeon may expect arthritic changes which tend to limit the joint movement, and they must be guarded against by a sufficient period of immobilization after reduction. Myositis ossificans involving the brachialis anticus and other muscles may follow after reduction of elbow dislocations from the active proliferation of osteoblastic cells which have wandered into the muscles from torn periosteum.

[1] Deutsch. Ztschr. f. Chir., 1914, cxxvi, 213.

Treatment.—Reduction must be accomplished as soon as diagnosis is made and can be done in several ways. Direct traction downward on the forearm in the direction in which it lies, with counter extension on the arm above made by an assistant, is the easiest method. When the traction separates the joint surfaces and unlocks the coronoid, if it is caught behind the trochlea, the forearm is brought into flexion as the traction is maintained by swinging it forward, and reduction follows. This method, with or without general anesthesia, succeeds in practically every fresh posterior luxation, regardless of the muscular development, and avoids much additional laceration of the ligaments. Most elbow dislocations have caused a great amount of tearing of the anterior and lateral ligaments, so that the greatest obstacle to reduction is the spasm of the muscles crossing the joint.

Other methods are used successfully, a favorite one employed on young children consisting of direct pressure downward of the surgeon's thumbs against the displaced olecranon, while the hands grasp the arm above the joint and furnish counter-extension. The displacement is thus corrected by pushing. The surgeon may place his knee against the luxated elbow and by using it as a fulcrum and pulling the wrist down and around into flexion may cause easy reduction. He may also use for this purpose a solid mass like a bed post, bending the forearm around it. These methods are open to objection, because, since considerable force is used to drag the forearm bones into position, the olecranon may be broken off by muscle pull, or the coronoid, or trochlear surface may be injured by direct bony pressure. The capsular and lateral ligaments may also be torn more widely than they have been by the causative trauma. When the joint is very mobile and the ligaments are widely torn, reduction is easily accomplished by the attendant grasping the arm in one hand just above the elbow and making traction downward and forward on the wrist with the other hand, swinging the forearm up into place by flexion. With marked displacement backward and upward, when the coronoid is thoroughly engaged behind the trochlea, some hyperextension may be necessary. The forearm is bent backward into hyperextension, the humerus is pushed forward slightly just above the elbow by an assistant until the bone unlocks, and reduction is finished by downward traction and subsequent flexion of the forearm to swing the coronoid up around the trochlea. Complications caused by fracture of the condyles, of the olecranon, and of the radial head are not considered primary indication for operative treatment, unless reduction by manipulation and moderate force under anesthesia cannot be accomplished. I believe the best course is to obtain a reduction even if any of these fractures are present. The joint capsule and ligaments are then permitted to heal usually with the arm in flexion, and very often the fracture will also heal and cause little disturbance. When the acute result of the dislocation has subsided and it is found by examination that callus or a misplaced bone fragment interferes with function, open operation should be performed for removal of the offending

osseous fragment, the least possible amount of damage and opening being done. Fracture of the olecranon can be cared for by strapping of the upper fragment after reduction of the luxation, or by extra-articular wiring or nailing. Fracture of the head of the radius needs a long immobilization in a fully flexed position with subsequent excision, if there is interference with joint motion or pressure on the radial nerve. Operative treatment by arthrotomy is reserved for the rare irreducible fresh cases, the cases complicated by nerve, blood-vessel, and bone injury, and for the old unreduced cases.

After-treatment in an ordinary case consists in retention of the forearm in a moulded splint in a position of about 60 degrees flexion for two or three weeks, or until passive motion in the direction of extension is painless, painlessness being an indication of complete healing of the ruptured capsule. After three weeks the arm is given light passive movements, is massaged freely, and is left out of the splint in a sling. Each day the sling is lowered, active movements short of pain production are encouraged, and function gradually returns in full. Patients possessing a tendency to a proliferative osteoarthritis are not hurried in after-treatment. The joint is never moved to a painful point, and although slight changes in the dressing may be made every day, the convalescence is prolonged to avoid painful joint irritation.

Old Elbow Dislocations.—This subdivision really includes only those cases of luxation which have remained unreduced for some weeks until the secondary changes about the joint preclude reduction by ordinary manipulative measures. Because the operative technic is similar, the steps of arthrotomy for this condition must be used to cover partial or complete ankyloses which follow reduced dislocations. Parosteal bone growths, small fractures, or synovial ankyloses which indicate complete arthroplasty or bone resection may be present.

Most old elbow dislocations are of the posterior variety. They may also be partly external or internal, a matter of little importance compared to the stiff position of the arm in extension. A few degrees of flexion may be possible, but the arm cannot be actively placed in a functionating position, the forearm cannot be rotated, and all movements must come from the shoulder. The patient is unable to bring the hand to the face or head for any purpose and the awkward position of extension is embarrassing. (See photograph of case, Fig. 322.) Reduction by manipulation and traction have been accomplished after many weeks, but there is great danger of fracture of the bone points and also of subsequent complete ankylosis when the forearm is finally brought into the desired position. Mr. Robert Jones has advised for old supracondylar fractures of the humerus or old posterior dislocations, when the arm is in the position of an obtuse angle with not more than 20 degrees movement, forcible flexion of the forearm under anesthesia. Repeated attempts are often needed. At first a few degrees of flexion are gained and held by a bandage. In a few days the patient is again anesthetized and a few more degrees of flexion

are added, until finally complete flexion is obtained. The arm is left bandaged in that position for at least two weeks, after which active and passive motion toward extension are urged, and a good range of movement often results. The great danger of the forcible flexion is fracture.

Pathology.—When an old unreduced elbow dislocation is exposed, the surgeon is not surprised that reduction had not been possible by manipulation and traction. Roentgenograms taken in both an antero-posterior and a lateral plane will be guides in the planning of the operation, as far as the pathology is shown by bone shadow. Between the displaced olecranon, the sigmoid fossa, and the humerus, strong cicatricial bands have formed which prohibit flexion (Figs. 323 and 324).

Fig. 322.—Old backward dislocation of the elbow ankylosed in complete extension.

Callus has been deposited in the olecranon and coronoid fossæ, about the olecranon, wherever the periosteum has been torn, and in the surrounding muscles. The brachialis anticus and triceps are likely to be invaded. The greater sigmoid cavity is also filled with a mass of cicatricial tissue, so that if the bones could be pulled back into position on the trochlear surface the cavity would no longer fit them. Children who have actively osteogenetic tissues show greater callus formation in unreduced dislocation. On the anterior aspect of the joint the capsular tear generally leaves a curtain of fibrous tissue, which hangs down over the trochlea and seeks new attachment to the forearm bones. The torn lateral ligaments have healed in a cicatricial mass adherent to both the humerus and the forearm bones, and they form a firm obstacle

to reduction. The nerves crossing the joint may be compressed in the contracted connective tissue.

Bone injury is common. Tubby[1] reported a case of postero-external dislocation of the elbow of six weeks' standing. Supination was reduced to 50 per cent., and the internal epicondyle of the humerus was fractured and enlarged by callus formation (Fig. 325). A similar case operated on by Henderson[2] showed an excessive growth of bone about the lower end of the humerus, with fracture of the internal condyle. I have operated on four old dislocations in the last year, one with fracture of the radial head, one of the external condyle, and

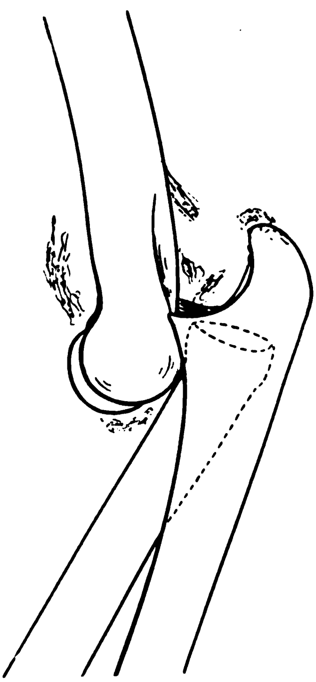


FIG. 323.—Old unreduced backward dislocation. Note the callus developed under the stripped periosteum.

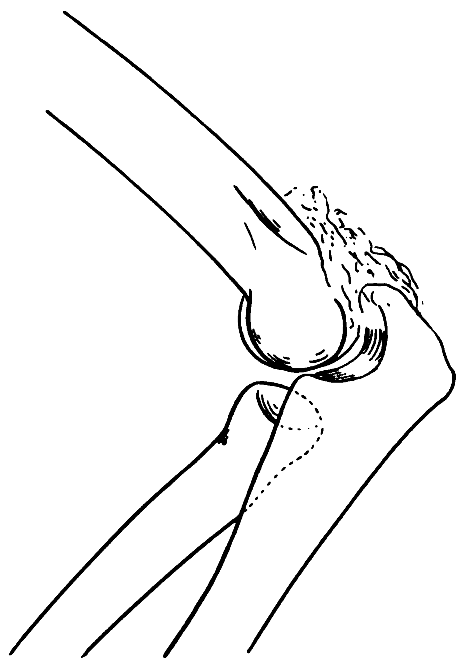


FIG. 324. — Reduced backward dislocation followed by ankylosis at a right angle. Note the callus in the olecranon fossa.

two of the internal condyle. Hodge[3] found an old postero-external dislocation with a crack an inch long and a loose piece of the external condyle. Donati[4] found a fracture of the external condyle in an old posterior elbow dislocation and states that condylar fracture is present in 55 per cent. of all cases. Pibram, at the Surgical Congress in Paris, October, 1913, reported 16 cases from von Eisels-

[1] Proc. Roy. Soc. Med., London, 1913–14, vii, Surg. Sect., p. 157.
[2] Med. Press and Circ., London, 1915, N. S. xcix, 317.
[3] Ann. of Surg., lv, 777.
[4] Arch. di Ort. 12 Maggio, 1912.

berg's clinic in Vienna, and Walzel[1] later brought the total of the cases from this clinic to 19. Of their 19 cases there were 6 in which physical examination and roentgenogram failed to reveal any fracture or bone tearing, yet at the operation on these cases callus masses were found produced by torn periosteum or splinters of bone. These masses existed between the olecranon and the humerus, or in front between the coronoid and the humerus, and filled the olecranon fossa or bound the radial head. They also noted the great thickening and restricting presence of the torn anterior capsule. In 13 of the 19 cases some bone injury was discovered. Both bones of the forearm showed injury on the joint surface in 4 cases, the internal condyle was broken in 5, the radial head was damaged in 1, and in 2 the olecranon was fractured so that small fragments lay in the coronoid and olecranon fossæ and in the incisura semilunaris. In most of these instances the fragments had healed on by callus, so that full joint excursion was impossible.

The 6 cases uncomplicated by fracture reported by Walzel showed full ankylosis in 3, flexion limited to 120 degrees in 2, and to 160 degrees in 1. Of the 13 cases grouped together on account of bone lesions, 5 were completely ankylosed, 2 allowed a passive motion of 60 degrees, and 5 a motion of from 10 to 30 degrees. One can plainly understand that forcible flexion and manipulation are quite unavailing for reduction, and are likely to lead to further fracture without satisfactory reduction when much force is applied.

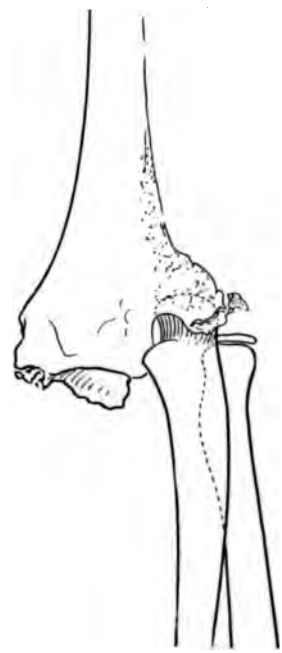


FIG. 325. — Old posterolateral dislocation with callus development. Irreducible by manipulation.

Operative Treatment.—Open operation for old elbow dislocations may be divided into (1) arthrotomy with (*a*) simple replacement, or (*b*) arthroplasty.

(2) Resection of the whole end of the humerus with or without the use of arthroplastic flaps.

(3) Atypical resection of loose bone bodies, masses of callus or the radial head.

The surgeon offers the patient the opportunity of bettered position of the forearm and of relief from nerve pressure, even if a subsequent ankylosis occurs. With the arm in a more useful position, the deformity is not so noticeable, and function is proportionately improved. The patient incurs the risk of ankylosis, infection, and possibly later amputation in a very small percentage of cases, but we have learned

[1] Verhandl. d. deutsch. Gesellsch. f. Chir., Berlin, 1914, xliii, 2 Theil. p. 126; Arch. f. klin. Chir., Bd. cv, 1 Heft, 2.

that arthrotomy is not dangerous and can become a routine operation in the hands of those trained for it. Nicoladoni[1] reported 11 cases of arthrotomy for old dislocations, 2 of which were of the elbow, and both gave fair results. Lexer, Murphy, Bunge, and Dollinger have proved this possibility of result. In 1908 at the German Surgical Congress Bunge collected 42 cases of arthrotomy at the elbow. Bunge had performed 17 cases of bloody reposition of elbow dislocations in thirteen years at the Königsberg clinic. Those performed through a bilateral incision at the joint gave a ratio of 50 per cent. good results, while those with a unilateral incision showed but 25 per cent. good results. Dollinger[2] reported 45 cases of old traumatic dislocation of the shoulder, hip, and elbow. Of these 28 were subjected to arthrotomy, and he concluded that resection of joints should only be made as a last resort when it was found that arthrotomy offered no hope of a functionating joint. Bockenheimer[3] advocated arthrotomy with the strictest asepsis and a minimum time of exposure of the joint structures.

The pathological changes about the joint are such that operation alone offers hope of betterment of the deformity.

Operative Technic.—The incision may be bilateral or unilateral, depending on the operator's choice, the lateral character of the dislocation, and the knowledge gained from the roentgenogram. The various single incisions are down the back of the humerus slightly to one side of the projecting olecranon, down the external aspect of the joint over the external condyle, or along the inner aspect of the joint just above the level of the ulnar nerve. Double incisions can be made, one on either side of the olecranon about one and a half inches apart, first advised by Murphy for arthroplasty, or one over the inner and over the outer condyle of the humerus nearer the anterior surface. In Walzel's 19 cases the following approaches were made: 6 outer incisions, 1 inner, 2 posterior, and 10 bilateral. After trying the double incision I have finally come to using an incision 8 inches long over the inner aspect of the joint above the path of the ulnar nerve. The nerve is first isolated by being lifted from its bony bed and held retracted out of the way. Complete excision of fibrous tissue and healed capsule is then begun, the operator clinging closely to the bone surfaces. A wide dissection is necessary, and all callus and cicatricial masses must be removed by sharp tools. I find small curved artists' chisels are especially adapted to cleaning out the olecranon and coronoid fossæ, and the capsule, lateral ligaments, and triceps tendon are not spared in dissecting efforts directed toward freeing the bones. Every part of the joint should be fully exposed to view and be made movable. By hugging close to the bone surface in reflecting the obstinately adhering anterior portion of the capsule, the surgeon

[1] Wien. med. Wchnschr., 1885, No. 23.
[2] Ergebn. d. Chir. u. Orthop., Bd. iii, 83.
[3] Münch. med. Wchnschr., 1911, lviii, 2560.

avoids bloodvessels and nerves. The bones may be bent out of the soft tissues to permit a thorough cleansing of the adherent scar tissue. Generally a reduction can be accomplished after such a thorough exposure, and the capsular and ligamentous tags can be sutured together over the joint. If bony parts still obstruct reduction, I believe it is better to deepen the greater sigmoid cavity, to shorten the tip of the olecranon, or resect the head of the radius before resecting the lower end of the humerus. If there is much bare bone, or any fear of subsequent ankylosis, a flap of fatty tissue is dissected up from the anterior surface of the soft parts about the elbow and is swung down, attached by a pedicle, between the bone surfaces. In one case I found this flap was necessary, and although reduction could be made with all bones intact, I was compelled to resect the radial head to avoid destructive pressure on the fat flap when the arm was brought into flexion. The operation is preferably done without a constrictor, because it requires from one and a half to two hours to complete and because hemostasis is an essential part. With the constrictor it is impossible to avoid considerable oozing after the wound is closed, and the hematoma which forms interferes with the result and leads to infection. The subcutaneous tissues are closed by interrupted catgut sutures—a continuous suture may pull out entirely—and the skin is completely closed by silkworm gut or clips, in spite of any tension which may exist. Many cases develop stitch-point infections, or the superficial skin sloughs in small areas, but as long as the infection does not penetrate into the new joint no fear of unsatisfactory result need be entertained.

The arm is dressed in about 60 degrees flexion in a firm moulded splint of plaster and is kept immovable for about a week, unless the dressings become saturated and require removal. Once I had quite extensive skin sloughing from pressure and once stitch abscesses in the superficial tissues. All cases healed without deep infection. The 19 cases of elbow arthrotomy reported by Walzel resulted in primary union in 13. There were 4 cases of afebrile hematoma, 2 of some secretion with fever, and 1 requiring incision for drainage. Of his 10 cases treated by bilateral incision only 1 showed infection and fever, and that gave a good result. When a case becomes infected after operation, it should be afforded sufficient drainage and be held immobilized at a suitable angle of flexion of the forearm.

The after-treatment consists of daily light passive movements without pain in the second week, the arm being dressed in a light moulded splint. In the third week the splint can be dispensed with, the patient is encouraged to make active movements, and after the fourth week all possible active use of the hand is necessary. The results are generally quite satisfactory to the patient. The forearm is in a useful position—a woman can get her hand to her face and hair, and all patients can use the hand for eating and other functions. The amount of flexion and extension possible varies. I have had results from 80 to 120 degrees of motion in the elbow-joint. The joint

gradually becomes stronger and will support much weight. Hodge[1] obtained 75 degrees motion in his case after one month. Tubby obtained active motions of 90 degrees after three weeks. Seventeen of Walzel's 19 cases were traced for results. Three resulted in ankylosis, with better position, 7 had a practically normal joint, 7 had a good functionating joint with a minimum excursion angle of 80 degrees and a maximum of 100 degrees. Out of the 19 reductions by arthrotomy 15 useful extremities were obtained.

Lateral Dislocations of Both Bones of the Forearm.—(*a*) Outward dislocations. (*b*) Inward dislocations. Lateral dislocations of both bones may be outward or inward from their normal longitudinal axis, but the term true lateral dislocations implies that the articulating surfaces of the forearm bones remain in their relative position to the transverse axis of the lower end of the humerus. This means that there is no posterior or anterior displacement and that the coronoid lies in front of and the olecranon behind the axis of the trochlear surface of the humerus. Lateral displacements may be complete or incomplete; both bones may be widely displaced free from the end of the humerus, or one bone may still lie in contact with the trochlear or condylar surface.

(*a*) **Outward Dislocations.**—Outward dislocations are the commonest variety of lateral displacement, and they are divided into three varieties:

(1) Complete outward dislocation with pronation of the forearm.

(2) Complete without pronation of the forearm; a very rare kind.

(3) Incomplete outward dislocation.

1. Complete outward dislocations with pronation of the forearm have been recognized more than a hundred years, and yet there are not more than 35 cases on record. The causes are not well understood but may be falls on the pronated forearm or elbow or direct violence on the inner side of the forearm. One case which I have seen was caused when the patient's forearm was caught in a swiftly moving, broad-power belt, and sustained a violent wrench from within outward, while his arm was at right angles to the long axis of the belt. The forearm is slightly flexed and is pronated, the sigmoid surface of the ulna being turned inward by rotation on its long axis.

2. In complete outward dislocation without pronation both bones are carried laterally displaced outside of the lower end of the humerus and yet not pronated. This form is exceedingly rare.

3. Incomplete outward dislocation is probably not so rare. The sigmoid cavity of the ulna has not passed completely outside of the trochlea, or at the most has come to lie against the external condyle, the coronoid still being in front of the humerus (Fig. 326).

Pathology.—In the first type with rotation both the lateral and the anterior ligaments must be widely lacerated. The forearm is pronated and flexed so that the head of the radius lies on a higher level than the

[1] Loc. cit.

sigmoid of the ulna, which lies turned inward, resting against the outer surface of the external condyle of the humerus. The radial head may lie slightly inward from the ulna, and the orbicular ligament is not often destroyed. The ulnar and radial nerves may be injured by pressure or laceration. The epitrochlea may be broken off, as reported by Stimson and Heuter,[1] and become an obstacle to reduction. In the second class the forearm bones are carried completely outside of the end of the humerus and are not rotated, so that the inner edge of the sigmoid of the ulna, which looks forward as normally, lies against the outer side of the external condyle, the coronoid in front and the olecranon behind. In either of these forms the muscles attached to the epitrochlea may be completely torn off; theoretically they still, in the pronated variety, retain their attachment, and by their action have caused the rotation of the luna.

Fig. 326.—Incomplete outward dislocation with fracture of the condyle. The bone fragment was not an obstacle to reduction, but the piece above had to be removed.

In the third type, the incomplete outward dislocation, the lateral ligaments must be more or less completely ruptured and the anterior ligament also torn away. The radius is displaced outward and probably a little forward, retaining its attachment to the ulna. The sigmoid cavity of the ulna has moved outward part of the way, so that it comes to lie against the outer lip of the trochlea or against the capitellum. The epitrochlea may be broken off and displaced up into the trochlea to obstruct reduction, as in the complete lateral dislocations. Nicoladoni's experiments on the cadaver seemed to prove that the epitrochlea was torn off by the avulsion of the attached group of forearm flexors rather than by the tearing out of the capsular ligament, which is inserted at its extreme lower edge only.

Symptoms and Diagnosis.—In all forms of outward dislocation the elbow is slightly flexed and it is broadened, thus exhibiting a distinction from backward luxations. Usually also the forearm is pronated; it is extremely so in the forms with pronation. The long axis of the forearm may be parallel with the arm but lies outside. There is some motion present, sometimes an astonishing amount, because there is no bony interference with flexion, and more flexion is permitted than

[1] Stimson, Fractures and Dislocations, 7th edit., p. 698.

in posterior dislocation. Rotation is limited. Examination of the elbow shows the unduly prominent internal condyle, with the skin stretched tightly over it. The transverse measurement at the elbow may be doubled. Palpation reveals the sharp edge of the internal condyle and epitrochlea, and in complete outward dislocation the rounded surface of the trochlea may be felt. Posteriorly the olecranon can be felt displaced outward, and the head of the radius lies either anterior or lateral and is very prominent. The triceps tendon can be seen and felt, extending to the outward displaced olecranon. When the forearm is pronated in complete luxation, the olecranon points directly outward, the sigmoid fossa is turned in against the external condyle of the humerus, and the radial head becomes the most palpable mass just in front of and outside of the external condyle. The extensor muscles form a bulging mass on the anterior surface of the elbow.

Treatment.—Reduction is not difficult in fresh outward dislocations, unless the epitrochlea has been broken off and lies on the trochlea to prevent the ulnar sigmoid from fitting over it. In the forms of complete luxation the forearm is extended with traction, and the ulna and radius are pressed inward and over into position as the forearm is brought into flexion. This manipulation does not require great force, because the ligaments have been so widely torn that the bones are mobile and slip over each other easily. If the forearm is in pronation, as the reduction is accomplished by traction and pressure, the hand is swung around into supination to bring the ulnar sigmoid into normal relation with the trochlea, the head of the radius being turned to the outside of the joint and pushed under the capitellum.

In the incomplete type the surgeon wishes to lift the ulnar sigmoid from its position outward between the trochlea and capitellum over onto the trochlea. This proceeding may be accomplished by extension of the forearm with traction while an assistant pushes the forearm bones inward into place. If this movement fails, one may obtain reduction by making some abduction to free the ulna from its locked position against the humerus. Slight abduction is of assistance if the radial head still lies partly beneath the external condyle, because that point is used as a fulcrum for the leverage. After the ulna is freed the forearm bones may be pushed over into place. If the orbicular ligament which holds the radial head to the ulna is ruptured, this lever will not be efficacious, and the olecranon must be pressed upon, that it may be moved over into place.

Incomplete outward dislocations have frequently been complicated by fracture and displacement of the epitrochlea onto the trochlea and this small mass of bone becomes a great embarrassment in reduction. Partial reduction may be accomplished with this bit of bone lying between the humerus and ulnar sigmoid, but joint motion is not free, and there is usually some persisting abduction of the forearm. The fragment may be squeezed out of the joint and into position on the inner side of the arm by lateral flexion of the forearm, which is bent to a right angle. This endangers the skin on the inner aspect of the

joint. It may be punctured, or the ulnar nerve may be stretched. Open operation for the removal of the foreign piece of bone by an approach on the inner side of the joint is the treatment of choice.

Inward Dislocations.—Inward dislocations are never complete in type. The ulnar sigmoid lies in part contact with the trochlea, and the radial head may not move from the capitellum, so that the dislocation may really be one of the ulna inward alone. However, the head of the radius usually lies within the capitellum against the ridge of the trochlea, and it forms there a new articulating facet. The lateral ligaments are torn and the anterior ligament may be merely stretched and not lacerated. If the radial head remains in normal position, the orbicular ligament must be torn. It may lie in front of or even behind the end of the humerus.

Symptoms and Diagnosis.—The forearm seems shifted inward, its axis corresponding with that of the humerus. The internal condyle of the elbow is less prominent than the opposite joint, the olecranon fossa is empty to palpation, and the olecranon can be felt inside of this space riding over the epitrochlea with a corresponding deviation of the triceps tendon. The external condyle may become prominent, and the radial head is lacking below but is found back of the humerus in most cases. Motion in the joint is free because of ligamentous tearing, unless there is a large hemarthrosis.

Treatment.—Reduction is easily accomplished by traction and extension of the forearm aided by pressure against the olecranon or upper end of the ulna outward. If this manipulation fails, the forearm may be abducted during the traction, whereupon the lateral pressure pushes the ulna into place.

Prognosis and results of lateral dislocations are good. There is little tendency to recurrence, if the arm is immobilized in a light plaster splint for a week. Function rapidly returns, and ultimate results are satisfactory, with some limitation of joint motion after the ligaments have healed and cicatrized. When the luxation is not reduced, function may become quite serviceable, although motions are restricted. This statement is truer of incomplete than of complete dislocations, which are subjected to the traction of unbalanced muscles or which are greatly limited in motion by the position of pronation. Effort should be made to reduce fresh dislocation at once; old cases can be treated in accordance with the outlines of treatment laid down for old posterior dislocations, each case becoming a problem for the surgeon to solve on its own findings. Resection should be the last step and arthrotomy the usual operation.

Dislocation of Both Forearm Bones Forward.—Forward dislocation of both bones at the elbow is extremely rare and may be accompanied by fracture of the olecranon, the proximal fragment of which, with the triceps attachment, remains *in situ*. When the fracture is so important to the displacement forward, the case should not be considered a true dislocation. Both bones may be displaced anteriorly, so that the posterior surface of the olecranon lies against the anterior

surface of the trochlea, or in a less complete form the tip of the olecranon lies against the trochlea without displacement up onto its anterior surface.

The causes in the reported cases have varied from falls on the palm and flexed forearm to violent twisting strains which involve the hand and forearm. Canton[1] reported a case in which the patient, an adult male, was thrown from his wagon and struck on his extended hand, the forearm immediately crumpling beneath his chest. Stauton[2] records an instance in which the patient sustained a fall on the flexed elbow. The anterior dislocation may result from torsion or pronation stress exerted on outward lateral dislocations, so that the forearm bones are pulled over in front of the elbow-joint.

Pathology.—The lateral, the anterior and the posterior ligaments must be torn to allow for the displacement. In the complete form, when the upper ends of the forearm bones ride up onto the anterior humeral surface, the triceps tendon must be torn from its insertion. This was so in Canton's case. The luxation may become open by the projection of the humerus through the tense skin on the back of the joint, or by the forearm bones thrusting a way through the tissues on the anterior surface. The orbicular ligament and the upper part of the interosseous ligament may be torn. In the forward displacement the flexor group of muscles attached to the lower end of the humerus are torn off, and the ulnar nerve may be also torn apart. Fracture of the olecranon permits an easy dislocation forward, if the ligaments are severed, and this condition really belongs in the fracture group. Concomitant fractures of the epitrochlea and the condyles are contained in the reported cases. Lambert[3] did an open operation on a forward dislocation. The orbicular ligament was unruptured, the triceps were only partly detached from the olecranon, and the internal epicondyle which had been detached from the humerus was found displaced with the ulna and attached to the coronoid. Bone fragments were removed and a replacement made with a happy result.

Symptoms.—In the complete variety the limb must be in extension, usually 120 to 140 degrees, and some flexion, even to a right angle, may be possible passively. The flexed forearm is lengthened slightly when the olecranon is not broken, but in extension there is shortening. The most striking finding is that the forearm can be hyperextended, with no great pain, and as this action is performed the head of the radius and the coronoid of the ulna can be felt beneath the tissues in the anterior fold of the elbow. The olecranon is missing on the posterior aspect of the joint, the fossa is empty and palpable, and the joint is thickened anteroposteriorly, not laterally. In the incomplete form the tip of the olecranon is held against the trochlea by the tense triceps tendon, which still retains its attachment, and the forearm is in flexion. The olecranon sticks out prominently below the end of the humerus, and the forearm is lengthened in extension.

[1] Dublin Med. Jour., 1860, ii, 24.
[2] Brit. Med. Jour., 1905, ii, 1520.
[3] Ann. of Surg., liii, 866.

Treatment.—Reduction has been accomplished in every case except Canton's which remained unrecognized and unreduced for several weeks and in which supracondylar amputation was finally performed. For reduction the forearm is flexed, traction is made on it, and the forearm bones are pushed out away from the humerus at their upper end to permit the olecranon to slide back into place. The operator's knee may be placed in the anterior elbow fold to act as a fulcrum for this leverage. Complete dislocation with the forearm bones riding high on the humeral surface must be converted into the incomplete type by flexion and traction and the olecranon then shoved down into place. The subsequent course and prognosis depend on the presence or absence of open wounds about the joint, laceration of muscles and ligaments, and infection. Ten to fourteen days' immobilization is given the closed dislocation before any passive motion is started. Open or infected luxations are treated according to the general principles applied to open fractures and dislocations.

Divergent Dislocation of the Forearm Bones.—In this rare type of forearm luxation the bones are dislocated simultaneously but do not accompany each other, that is, they spread apart to permit the lower end of the humerus to be shoved between them. There are consequently two types of divergent dislocation, depending on the position of the arm at the time of accident and the direction of the force. If the forearm is completely pronated and the force drives the forearm bones up onto the humerus, they can be displaced only after the lateral, anterior, and posterior ligaments of the elbow-joint are torn apart and the orbicular ligament and the interosseous membrane which hold the radius and ulna together have been bursted. A force powerful enough to accomplish this end and directed at the right angle is rare, and the ligaments practically never yield, the bone generally suffering fracture. With the forearm pronated, the separated bones are displaced on the humerus, the radius on the anterior surface and the ulna on the posterior. That constitutes the most common form. The other form, of which only two cases are recorded in the literature, Guersant's[1] and Wight's,[2] is the transverse, in which the arm is probably supinated at the time of accident, and the ulna is driven up on the inner side, the radius up on the outer side of the humerus. Variations of these displacements have been described, probably caused by secondary positions from continued trauma or muscular action.

Symptoms and Diagnosis.—The forearm may assume any position of slight flexion to complete extension and rotation, and the elbow is thickened anteroposteriorly. On account of the swelling and shortening of the forearm the condition may be mistaken for backward dislocation, or supracondylar fracture of the humerus. There is pain and no active movements, while passive movements of flexion and extension are limited. Bockenheimer[3] reported an unreduced case

[1] Warmont Rev. Med.-Chir., xvi, 303.
[2] Physic and Surg., Ann Arbor, February, 1893.
[3] Münch. med. Wchnschr., 1911, lviii, 2560.

of divergent dislocation in a twenty-year-old man. He had been knocked down, falling on his extended and pronated forearm, which remained fixed in extension after the accident. The displacement had lasted many weeks, and examination showed that the radial head was located on the flexor side and the olecranon on the extensor side of the humerus (Fig. 237). In the normal position for the radial head there was a vacancy, and the olecranon fossa was also empty.

Treatment.—The forearm is manipulated in partial flexion with traction and counter-traction on the arm reducing the ulna much as in posterior dislocation. When that has been reduced, the forearm

FIG. 327.—Divergent dislocation of the elbow. A drawing made from Bockenheimer's case.

can be carefully extended and slightly adducted and the radial head pushed down into position by direct pressure. A fixed dressing in a position of about 120 degrees extension will probably prevent recurrence, although the published cases give scant information as to results. Bockenheimer had to operate on his case, which was unreduced after he had tried reduction by manipulation under anesthesia. He made a 12 cm. incision over the radial extensor side of the joint and avoided all the nerves. The ulna was first reduced, and then it was found that the radius head would not remain in position unless the forearm was put in a position of extreme flexion. The torn capsule was united with catgut, and within eight days after operation there was primary

union and the cast was removed. In three weeks active movements were started, and in two months there was full function in the elbow-joint, including pronation and supination.

DISLOCATION OF THE RADIUS ALONE.

1. Dislocation forward.
2. Dislocation backward.
3. Dislocation outward.

Luxation of the head of the radius is found frequently with fracture of the shaft of the ulna high up. The ulnar fracture, which is obvious on account of the angularity in its continuity, may cause the surgeon to overlook the injury of the radius. Every ulnar shaft fracture should be scrutinized for possible luxation or subluxation of the head of the radius, and in elbow injuries with swelling, loss of supination, and limited extension the elbow-joint must be included in the roentgenogram. Likewise in all dislocations of the radial head the shaft of the ulna must be inspected for possible fracture. Stetten,[1] reviewing this subject, found over 120 cases, about one-tenth of which were complicated by nerve injury. The exact mechanism of this double injury is not known. The radial head may be dislocated primarily, and the continuation of the force transmitted through the hand in falls may then break the ulna, because the strong interosseous fibers hold, and the radius retains its axial relation to the lower fragment of the ulna. Another possible explanation lies in primary ulnar fracture with a secondary rupture of the orbicular and other ligaments about the radial head, which permit its luxation when it acts as the sole transmitter of the violence to the forearm after the ulna has given way.

The radial head may be displaced backward and press on the radial or posterior interosseous nerves. The larger part of the cases causing nerve injury in dislocations of the radial head are those combining radial dislocation and ulnar fracture. Carrey[2] records a case of nerve injury from dislocation alone. Stetten's article, referred to previously, states that the case he reported of radial paralysis caused by ulnar fracture and radial head luxation was the ninth on record. Sherren[3] knew of two instances. He performed some experiments on the cadaver to study this lesion and found on dissection that both the posterior interosseous and the radial nerve were twisted around the radial head in such a way that after reduction of the luxation they slipped off. When the joint was redislocated they caught again on the displaced radial head and were considerably stretched. It was found impossible to rupture the nerves by hyperextension of the forearm. The integrity of these two branches of the musculospiral nerve is threatened in nearly every radial head luxation. When the head is displaced forward and outward one or both branches may be stretched. If the

[1] Ann. of Surg., xlviii, 275.
[2] Thése de Lyon, 1894.
[3] Injury to Nerves and Their Treatment, London, 1908.

luxation is forward and inward the nerves are usually not injured. A simple forward dislocation involves the radial nerve alone, a simple outward dislocation usually involves only the posterior interosseous, while in backward elbow dislocation neither nerve is likely to be injured.

Fisk[1] reported an unrecognized case of combined ulnar fracture and radial dislocation which was followed by Volkmann's ischemic contracture. He was able to find over 140 cases of the combined injury recorded. Five were operated on at once and 26 after an interval of several months. The ligaments about the head may prevent reduction, and the fracture is difficult to maintain reduced, because the forearm must be held straight to correct the ulnar deformity, and the radial dislocation tends to recur unless the forearm is flexed to hold the head against the capitellum. Some surgeons consider this combination a primary indication for open operation, either to plate the ulna or to reattach and reinforce the ligaments at the radial head.

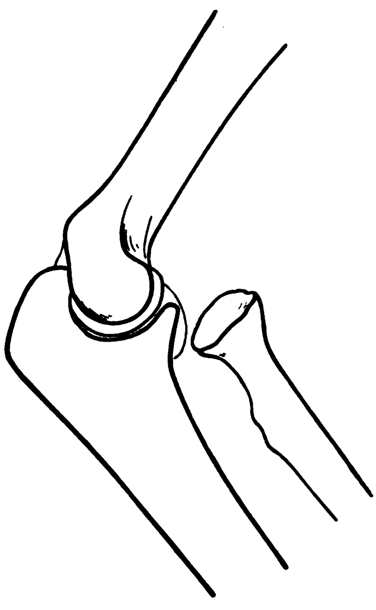


FIG. 328.—Dislocation forward of the radial head.

Dislocation of the Radius Forward.—This class is meant to include the pure luxations, to the exclusion of those complicated by fracture of the ulna just described and of the peculiar type of subluxation of the radial head in children, which will be discussed in a separate paragraph. Forward dislocation is the most common of the radial luxations (Fig. 328). The head is torn from its normal position and is shifted forward for a varying extent depending on the laceration of the ligaments, so that in extension of the forearm the head of the bone lies forward and when the forearm is flexed the head rises above the normal position, where it can be felt or seen in the shadow of the roentgenogram.

Direct violence on the upper part of the forearm, falls on the hand, and extreme pronation of the forearm are the causes. If the orbicular ligament is lax, violent contraction of the biceps muscle may produce dislocation by traction exerted through the insertion of its tendon. In children the type of subluxation induced by pulls on the forearm, probably a little hyperextended is clearly understood, and in adults

[1] Ann. of Surg., lvii, 266.

it seems that abduction and possibly pronation are necessary to cause the head to be luxated.

Pathology.—The author has operated on a fresh forward dislocation which could not be held in position. The orbicular ligament was torn off for three-quarters of its attachment, and the anterior ligament of the elbow had a rent in it through which the radial head half-protruded. The edge of the capitellum interfered with reduction until the forearm was hyperextended and the torn ligament was slit wider open. Reduction was then accomplished. Many reported cases show that the orbicular ligament has remained intact, but the anterior joint capsule has been ruptured. In old cases the radial head lies forward and slightly inward on the capitellum. It may lie close to the coronoid process of the ulna and be surrounded by healed fragments of torn ligament which have bound it in the new position. Cracks in the head extending as far as an inch down into the neck, or a chipping off of small bone fragments, have been seen in operated cases.

Symptoms and Diagnosis.—The forearm is in a position of partial flexion and usually pronated, so that there is some abduction when it is compared to the opposite limb. Flexion to a right angle can be accomplished, often without pain, but at that limit the joint is felt to lock and the forearm cannot be forced farther up. Extension may be complete. Examination of the elbow by rotation of the forearm discovers the radial head lacking from its normal position. It can be felt by one's tracing down the biceps tendon and lies inward and forward from the external condyle of the humerus. The lateral roentgenogram with the forearm extended shows the head of the bone riding upward.

Treatment.—In most recent cases reduction is easy. The wrist is grasped and traction is made in slight adduction, while the forearm is slowly supinated and direct pressure is made by an assistant down on the head of the radius. The forearm is then gradually flexed, and the assumption of a position of full flexion verifies the fact of reduction. Recurrence, common after this luxation, can be avoided by maintaining the forearm flexed. The pull of the biceps tendon on the radius is thus relaxed, and the ligaments are given an opportunity to heal with the bone in its normal position. Some cases are irreducible by manipulation and are cured only by operation. Reduction attempts under anesthesia with a fulcrum or block in the anterior cubital fold should be tried before operation. A short incision is made over the radial head, the bone is freed from adhesions, the capsule is opened to receive it, and it is pressed and manipulated back into place. If the replacement cannot be effected on account of new growth of bone and fracture of the head, and if full flexion cannot be attained after reduction, it is best to excise the head and hang a small flap of fascia over it to prevent bony outgrowth. The cases complicated by nerve injury or ischemic contracture, or recent cases which cannot be reduced by manipulation, are treated by arthrotomy without fear of disturbance of joint development and function. I have resected several

for interference with flexion of the forearm and one for nerve disturbance. Auzilotti[1] reported 2 cases. Uffreduzzi[2] collected 49 cases of congenital dislocation of the radial head, 5 of which were operated on. He also included 1 case of reduction of a recent dislocation by arthrotomy in a fourteen-year-old boy.

Dislocation Backward.—Dislocation backward of the radius at the elbow is rare. The radius may not leave entirely its contact with the capitellum, or it may be displaced posteriorly upward and behind the external condyle. The degree of displacement, as in all luxations, probably depends on the amount of capsular and ligamentous tear and accompanying fracture. Cameron[3] reported an instance in an elderly man who was caught between a wall and a cart and whose forearm was squeezed lengthwise with the hand in pronation. The violence forced the radial head out behind the external condyle just under the skin, and the cavity on the top of the head could be palpated. Other cases have been caused by falls on the pronated hand with the forearm in part flexion, the force being transmitted up the long axis of the radius in a manner which caused the bone to be displaced backward. Experimentally it is almost impossible to reproduce this type of dislocation on the cadaver, probably because the exact mechanical cause is not known and the influence of actively contracting muscle groups is lost.

No fresh cases have been examined; so the exact pathology is not known. Undoubtedly the orbicular ligament and joint capsule are torn, the edge of the external condyle may be sheared off, and the bone head lies behind the external condyle. The radius is also separated partly from the ulna, which remains in position. The diagnosis can be made on inspection when the head of the bone is found back of the external condyle and the hollow end is felt beneath the skin. The arm is usually flexed and pronated, and all movements at first are painful and restricted, but this limitation gradually subsides, and in old unreduced cases the function has been good with full motion in all directions except supination.

Treatment.—Recent cases are reduced by traction on the wrist and adduction of the forearm aided by direct pressure forward and inward on the radial head. After reduction the hand is supinated and the forearm fixed in partial flexion to safeguard against recurrence. In twelve to fourteen days the ligaments have healed sufficiently to permit gentle passive motion.

Unreduced cases demand operation, seldom to improve the function, but more often to overcome deformity. Stimson[4] has recorded Larkin's case of overgrowth of the radial head after backward dislocation (Fig. 329). The radial head should be excised if reduction is impossible and functional or cosmetic reasons indicate.

[1] La Riforma Med., March 14, 1914, xxx.
[2] Arch. di Orthop, December, 1913, p. 658.
[3] Lancet, 1884, i, 885.
[4] Fractures and Dislocations, 7th edition, p. 723.

Dislocations Outward.—Outward dislocations are rare and are frequently accompanied by fracture of the ulna. The causes are direct pressure outward on the radius, while the forearm is fixed in flexion. Wagner[1] reported 3 cases, all complicated by breaking off of part of the radial head. Löbker[2] reported 2 cases treated by excision. Shrötter[3] had previously collected 26 cases, 3 of which were complicated by radial fracture. The movements in the elbow-joint are greatly restricted, the elbow may appear broadened because the radial head lies on the outer side of the capitellum, and the head either is fixed

FIG. 329.—Excessive growth in length of the radius after dislocation of its upper end in youth. (Stimson.)

or can be felt to rotate in the new position. The orbicular ligament must be stretched or torn and probably the periosteal damage of the humerus and radius leads to a thickening by callus in the old cases.

Reduction is accomplished by traction on the forearm in adduction with direct pressure inward on the head of the radius, after which the forearm is flexed and held in position. If pain, restriction of motion, or loss of supination are present, the reduction may be attempted by open operation. In those cases in which manipulation fails and in

[1] Beilage zum Centralbl. f. Chir., 1886, xiii, 93.
[2] Ibid., p. 91.
[3] Arch. f. klin. Chir., xvi, 643.

old standing cases with thickening about the head operation is the only recourse. The prognosis is good; operated cases with resection lead to fair functional results.

DISLOCATIONS OF THE ULNA ALONE.

There are a few cases of undisputed isolated dislocation of the ulna at the elbow. The close attachment of the two forearm bones by the strong interosseous ligament, the blending of the ligaments at the elbow-joint, and the relative impossibility of directing force on one bone to the exclusion of the other make these luxations extremely rare. They are divided into dislocations backward and forward. One isolated inward dislocation exists in the literature,[1] a case of open and infected luxation with diagnosis delayed for over forty days. The misplacement of the ulna may have arisen from secondary causes in the infection and softening of the capsule and ligaments.

Backward Dislocation.—Backward dislocation of the ulna alone may also be partially outward, so that the coronoid lies just on the edge of the trochlear surface or completely behind it, and rising above the lower end of the humerus, lies in the olecranon fossa. I have seen this condition in one case of old posterior elbow dislocation which was reduced by open operation. The radius remained in position, but the ulna was slightly displaced backward, so that the coronoid did not come completely around in front of the trochlea, and flexion of the forearm was limited. An old complete dislocation of the ulna with rotation around the head of the radius was reported by Warbasse.[2] The patient was a thirteen-year-old boy who jumped from a wagon and fell, striking on the forearm and elbow. Deformity in the elbow was obscured by the swelling, but an examination nine weeks later demonstrated that the ulna was absent from the trochlear surface of the right elbow and the radius was in its normal position. Flexion and extension of the forearm was possible only through an arc of 10 degrees and flexion was limited beyond an angle to 150 degrees. Supination and pronation were only one-fourth normal and were painful. There was atrophy of the forearm. At the operation for reduction the ulna was found rotated 90 degrees and the sigmoid notch looked inward. A bony mass of new callus beneath the stripped up periosteum of the humeral condyle was chiseled off and the ulna was easily rotated back into its normal position. Extension and flexion became satisfactory but not quite full.

The causes are falls on the outstretched hand or direct pressure on the partly flexed rigid forearm. Usually the arm has been in complete extension; flexion is not possible, but pronation and supination are. The forearm is in slight adduction, like a gunstock deformity, which must exist to permit the ulna to slide backward and the radius

[1] Loison, Arch. de Med. et Pharm., Mil., September, 1890.
[2] Ann. of Surg., lii, 215.

to remain *in situ*. The position can be determined by inspection when the two elbows are compared. Little is known of the pathology. The internal lateral ligament is probably torn widely; the coronoid may be fractured. The brachial artery may be ruptured, and the orbicular ligament may not be torn unless the displacement is great.

Symptoms.—The symptoms are those of a forearm in rigid extension with some adduction deformity. Flexion is not possible. The elbow is thickened in an anteroposterior diameter, and the olecranon can be palpated higher up than normally on the rear of the joint. The radial head is in position and rotates with the forearm, and the edge of the trochlea, which seems to be tilted outward, fills the space in the front of the elbow. There is no crepitus, the rigidity, palpatory findings, and roentgenogram make the differentiation from epitrochlear and dicondylar fracture.

Treatment.—Reduction is performed by the attendant hyper-extending the forearm, supinating it and swinging it up into flexion. As an aid during the maneuver, pressure can be made over the olecranon. If manipulation fails, operation as described under Old Elbow Dislocations will be necessary.

Forward Dislocations.—Two cases have been recorded, one by Stimson[1] and one by Wight.[2] The internal lateral ligament and the flexor group of muscles were torn from the humerus, allowing lateral mobility of the elbow with some flexion and extension. The olecranon tip lay in front of and below the trochlea, and the inner anterior articular surface of the humerus could be felt by depression of the skin over the elbow. Reduction was easily performed by backward rotation and adduction of the forearm.

SUBLUXATION OF THE HEAD OF THE RADIUS.

This injury is quite common, and as it occurs exclusively in small children it is entitled to a separate description. Some of the older writers reported series of as many as 200 cases, but at the present time in hospital practice the cases are not frequent. Those which occur are either spontaneously reduced, cared for by the nurse and mother, or are reduced by the general practitioner in the course of his examination of the elbow. These subluxations occur in children from two to four years of age, although I find one case, recorded by Tubby[3] in an eight-year-old boy. The cause is lifting or jerking on the forearm and wrist by the nurse as the child is walking and a sudden jerking catch by the wrist traction as the child stumbles. Forearm pronation probably does not become a factor in the cause, for at the time of occurrence the child's arm is fully extended and the elbow-joint is firmly fixed, pronation and supination in that position taking place at the shoulder.

[1] Fractures and Dislocations, 7th edition, p. 718.
[2] Brooklyn Med. Jour., September, 1889.
[3] Clin. Jour., London, 1912-13, xl, 162.

Many theories of the cause have been advanced since the first good description by Duverney,[1] but the present opinion of surgeons seems to favor his original explanation. The condition is probably nothing more than an elongation of the radius in infants caused by the forcible traction on the wrist, which pulls the head downward away from the humerus. One must recall that, although the centre of ossification of the capitellum appears in the first year of life, the bones of the forearm and arm are widely separated in a roentgenogram by a cartilaginous area. Traction may easily cause longitudinal displacement of the radial head, with stretching of the loose and poorly developed capsule and orbicular ligament. The head of the bone is luxated below the annular ligament and is held there.

Symptoms and Diagnosis.—The symptoms are diagnostic. The child has immediate pain, often not only in the elbow but also in the wrist. The forearm is held motionless in pronation, hanging at the side, or flexed across the trunk if the patient is lying down. All active use of the elbow-joint is interdicted, and the child does not wish the arm touched. There are no definite findings on examination of the elbow, no swelling and little if any displacement of the radial head can even be noticed. There is tenderness on manipulation of the elbow-joint, and supination of the forearm is limited.

Treatment.—As previously indicated, the reduction may occur spontaneously, or the attendant in rotating the forearm may unconsciously force the head back into place. If there is sudden cessation of pain, and the child begins to use the arm, one may know that reduction has occurred. Many cases are misunderstood, are not diagnosed, but as the spontaneous reduction follows and function is restored the incident is forgotten, and the success in Chassaignac's cases, which were treated as nerve lesions, could doubtless be traced to the spontaneous reduction. Chlumsky[2] found that palpating and bending the elbow produced reduction. He found in one case a slight swelling over the radial head. Supination of the forearm with a slight upward push on the radius followed by flexion reduces the luxation, and function is generally resumed at once. A sling may be worn for a few days, or the arm can be pinned to the dress. In removing the child's clothing, hyperextension of the forearm should be avoided thereafter and there seems to be little tendency to recurrence, unless the upward jerk is repeated on the extended arm. The case of Tubby's referred to was subjected to operation because the posterior interosseous nerve was pressed upon, and the opposite elbow was showing symptoms of relaxation with a tendency to the same deformity. It was therefore considered best to cut down on the radial head and restore the orbicular ligament by means of an artificial silk ligament.

[1] Maladie des Os, 1751.
[2] Ztschr. f. Orthop. Chir., Stuttgart, 1911, xxix, 213.

CHAPTER XIX.

FRACTURES OF THE CARPAL AND METACARPAL BONES AND PHALANGES.

FRACTURES OF THE CARPAL BONES.

THESE bones are so closely packed together and so inaccessible to the usual methods of examination that fractures of them, in addition to being rare, have been seldom reported prior to the era of the Roentgen rays. Before 1896 many authorities, as Malgaigne (1850), Bardenheuer (1888) and Hoffa, considered that most fractures of the navicular bone were open and were accompanied by much laceration of the soft parts. With the help of the Roentgen pictures the literature is now furnished with many reports of fractures of individual bones or fracture and dislocation of one or more. The author desires to set out briefly a few important facts in connection with these fractures to attempt to simplify the subject for practical purposes.

Since dislocations frequently complicate carpal fractures or are a part of them, it is difficult to separate descriptions of each type of injury, and they will consequently often be found together. In the author's series of 10,702 fractures investigated at the Cook County Hospital, 22 fractures of the carpal bones were found.

Palpation of the wrist gives meager information as to the location and condition of the carpal bones, and on the ulnar side below the styloid process the pisiform can be felt projecting as a lump at the base of the palm on a level with the lowest transverse crease in the wrist. Below the radial styloid, at the base of the thumb metacarpal, the greater multangular bone can be grasped between the examining fingers. Other anatomical landmarks on the external surface consist in transverse lines. One drawn straight across on the level of the hamate bone crosses the capitate bone just above the base of the third metacarpal. If the hand is flexed after this line is drawn, a finger resting on this spot feels the head of the capitate bone slip into the space. The lower surface of the lunate bone lies just proximal to this.

The midcarpal joint line, between the two rows of carpal bones, is not so straight as the wrist-joint surface, and although it is also transverse to the long axis of the arm, it reaches an abrupt stop when the outer side of the capitate bone is approached. Here the navicular bone intervenes, and if the midcarpal joint line were continued directly outward it would cut through its middle.

Navicular Bone.—Fracture of this bone is now well recognized from many roentgenograms and reports of operated cases. It occurs

as about 0.5 per cent. of all fractures and possibly oftener. Developmental variations must be considered before diagnosis is made positively even by the Roentgen rays, and reference to such works as Dwight's[1] should be made. The navicular bone develops from two centres of ossification which may never fuse. This non-fusion was reported in 1865 by Gruber, and the bipartite bone was then considered an arrest in development. Wolff[2] calls one the cubital and the other the radial navicular and asserts that they are found in 0.5 per cent. of people examined. He reports 47 cases, 30 in men, 11 in women, and 6 not stated. Nine of these cases were bilateral, 20 in the left wrist and 7 in the right wrist alone. If the division line is directly in the middle, and there is no traumatic history, and the roentgenogram shows a clear interval between the bones with regular smooth edges, a congenital separation is possible. If the division lies to one side or other, decision is not so easy, and the possibility of old ununited fracture must be considered. It seems probable that the trauma which would cause a fracture would not go unnoticed (Fig. 330). A case of congenital division simulating fracture in a nineteen-year-old patient has been reported by Mouchet.[3] The left navicular was bipartite, and the ring finger was longer than the middle finger. Hirsch[4] believes that the so-called bipartite bones nearly all have their origin in fracture, as the latest collections of fracture statistics, aided by Roentgen-ray examination, demonstrate that out of ten radial fractures there are one or two accompanying navicular fractures. The records of the Cook County Hospital do not bear out this high proportion.

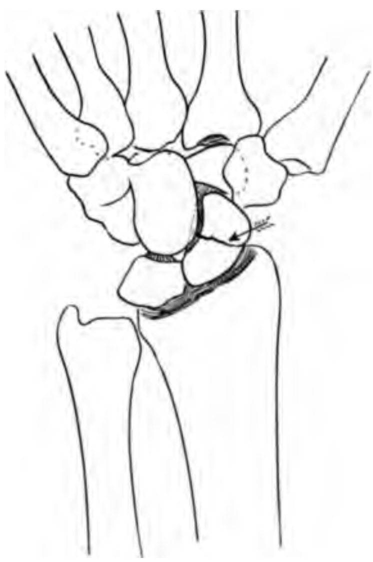


FIG. 330.—Transverse fracture of the navicular bone. This case might be mistaken for a bipartite bone.

Fracture occurs most frequently in the third and fourth decades, and usually follows falls on the palm as in Colles's fracture. The injury is often mistaken for Colles's fracture, or the two may occur simultaneously. Most fractures are through the neck of the bone, but in others the plane of fracture passes more toward the medial side (Fig. 331), so that the bone is divided into a smaller proximal and a larger distal fragment (Fig. 332). Laborers and adult males are those

[1] Variations of the Bones of the Hand and Foot.
[2] Deutsch. Ztschr. f. Chir., B. 69, 1401; Bd. lxx, 289.
[3] Revue d'Orthop., 1914, 3 S., v, 201.
[4] Ergebnisse der Chir. und Orthop., Bd. viii, 718.

most frequently concerned, and the right hand is more often involved, as it is thrown out to break a fall. There are a few instances of bilateral fracture.

The mechanism is as much disputed as that of Colles's fracture. Three principal methods suggested are:

1. Force of indirect violence from falls on the dorsally flexed hand or a falling body striking on the palm when the forearm is flexed is the first type of mechanism. From the brief description of the midcarpal joint given above, it is seen that on account of the position of the navicular, which interferes with a direct transverse line, it may be considered as belonging to both rows of carpal bones. If the wrist is flexed or extended, the second row of carpal bones makes an angle with the first row, and the navicular, in attempting to accommodate itself to both rows, is broken across the line of the midcarpal joint by

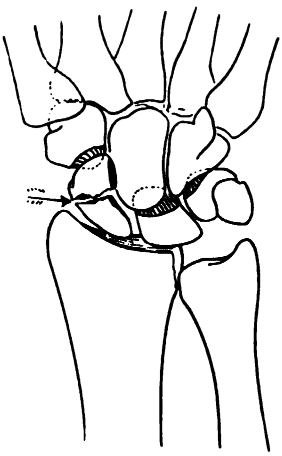


FIG. 331.—Fracture of the navicular bone with separation of fragments.

FIG. 332.—Fracture of the navicular bone with unequal fragments.

the strain. This mechanism is verified in those cases of midcarpal dislocation and fracture of the navicular in which the proximal fragment remains with the first row and the distal fragment is displaced with the second row. In violent adduction of the hand, the navicular may be strained across the radial styloid and broken, the styloid breaking also.

2. Compression force applied to the two extremities of the bone when the hand is in extension or flexion and forced abduction against an object is the second type of mechanism. The capitate bone presses against the distal portion of the navicular and the object on the inner side presses against that portion with a resulting force which tends to straighten out the bone, which breaks as a result. A blow on the thenar eminence in falling causes compression of the two rows of carpal bones between the joint surfaces of the radius and the hand.

The head of the capitate bone forces against the inner part of the navicular and the lunate, and the force is transmitted up to the radius if the hand is straight in the forearm axis and not abducted. This leads to an ordinary Colles. *If, however, the hand is more abducted and extended,* the force passes inward toward the styloid process, crushes the lower end of the radius and impacts it. The pull on the lateral ligament is frequently of such character that the styloid process is torn off or shoved off, and the navicular and lunate bones are compressed and possibly fractured. The softer structure of the navicular bone yields between the more solid capitate and radius (see Figs. 333 and 334).

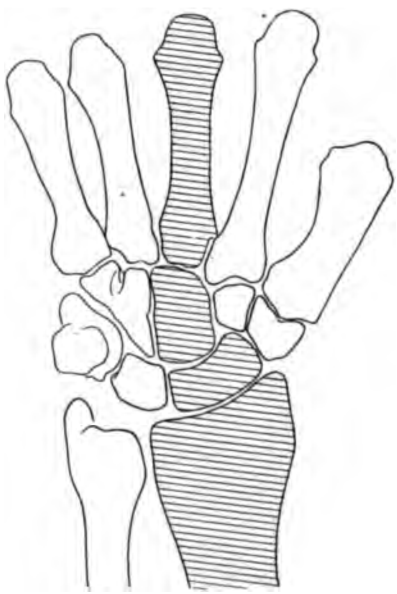


Fig. 333.—Illustration of the transmission of force through the third metacarpal to the forearm *via* the navicular, the hand being in radial flexion. (Adapted from Hirsch.)

Fig. 334.—Illustration of the transmission of force to the forearm *via* the lunate bone; hand in ulnar flexion. (Adapted from Hirsch.)

3. Direct violence suffered in falls on the back of the hand or by from a blow may cause fracture.

Clinically, there are two main classes of fracture which are important in cause, prognosis, and treatment. They are:

1. Fracture of the body, usually transverse to the long axis of the bone through its weak centre or neck.
2. Fracture of the tuberosity of the navicular bone.

Type 1 is an intra-articular or joint fracture, as the joint cavity is opened (see Fig. 335), but 2 is strictly extra-articular (Fig. 336). Fresh fracture through the body shows a line of separation, as in

ordinary transverse lesion of bone, but the older cases have been subjected to absorption of the cancellous portion by the influx of synovial fluid and the irritation of use, so that a distinct cavity is often found in the roentgenogram. Formerly this was considered a condition of osteitis in the navicular bone followed by fracture, and cases have been reported by Preiser,[1] but we now know that the fracture precedes the bone absorption. Murphy[2] believes that the transverse fracture is sometimes impacted and names that as a distinct type of navicular fracture which leads to the absorption of bone and cavity formation. The degree of crushing of the bone in the fracture varies, but the fact that it is split, the vascular supply is interfered with, and the cancellous tissue is exposed to the joint fluid

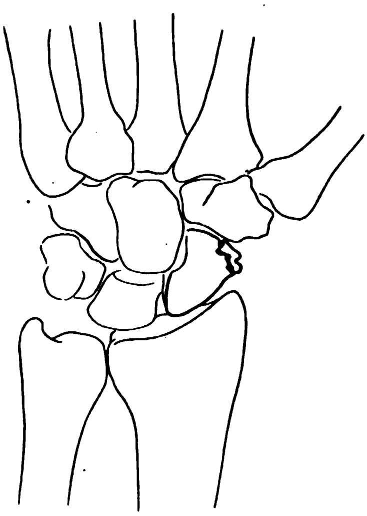


FIG. 335.—Fracture of the tuberosity of the navicular bone.

FIG. 336.—Illustration of the extent and location of the synovial surfaces of the wrist. The tuberosity of the navicular is seen to lie outside of the synovial surface.

has much to do with the appearance of bone absorption in the later roentgenograms. Some cases with simple transverse splits heal readily and promptly by bony union. I had such a case this winter. Others, on account of the supposed comminution or the rupture of the periosteum and synovial surface, are exposed to the irritation of the joint fluid, and bone absorption results (Fig. 337). Guye records 7 similar cases affecting the lunate bone.[3]

Fracture of the tuberosity is less frequent than that of the body and is an avulsion caused by falls on the forearm, the hand flexed to 90 degrees and strongly abducted, so that the radionavicular ligament pulls out its attachment to the navicular (see Fig. 335). This

[1] Fortschritte auf d. geb. d. Roentgenstr., 15, Heft 4.
[2] Clinics, iv. No. 3.
[3] Deutsch. Ztschr. f. Chir., Leipzig, cxxx.

mechanism has been experimentally verified by Cousins and also by Gallos.[1]

A difference in the position of the hand at the time the individual receives the trauma of the fall undoubtedly has much to do with the type of lesion. If the hand is in radial flexion and the force is received on the palm, it is transmitted through the middle metacarpal *via* the carpal bones to the radius, catching and crushing the navicular (see Fig. 334, adapted from Hirsch). Should the hand be in ulnar flexion this same violence is transmitted through the lunate bone and it is usually dislocated. The navicular escapes because it lies farther outward in this position between the radial styloid and the wrist bone of the second row, presenting its long axis in the direction of the trauma.

Symptoms.—The immediate symptoms are much like those of a sprained wrist except that there is greater rigidity. If a fragment of

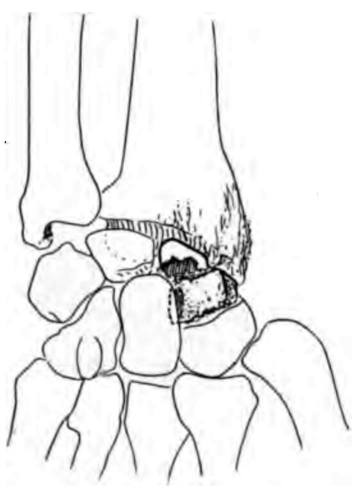


FIG. 337.—Old fracture of the navicular, showing bone absorption, cavity formation and open articular changes about the wrist which lead to great restriction of motion.

bone is displaced, and tenderness in the tabatière is elicited on slight pressure, there may be visible sign of injury and pain does not seem disproportionate. Swelling of the wrist below the styloid line and the end of the radius is quite constant, and there is loss of power of the hand grip and limitation of motion at the wrist, particularly extension and rotation. Crepitus and ecchymoses are not frequently found. Downes[2] obtained crepitus in 2 out of 10 cases. Codman and Chase[3] did not find either in 30 cases. It is necessary to compare with the uninjured wrist to ascertain the normal limitation of motion, which averages as follows:

Dorsal flexion, about 45 degrees.
Volar flexion, 60 to 70 degrees.
Ulnar flexion, 40 degrees.
Radial flexion, 20 degrees.

[1] Thèse de Lyons, 1897, 1898. [2] Ann. of Surg., xlvii, 72. [3] Ibid., xli, 721.

The cavity of the tabatière, which lies between the extensor pollicis longus on one side and the extensor pollicis brevis and abductor pollicis longus on the other side, is early filled or obliterated by swelling, and the radius and ulna are discovered to be normal, with the styloids in usual relation. The carpus may appear shortened on the radial side, and an additional test of value lies in striking a light blow on the knuckle of the third metacarpal at the base of the finger while the hand is in *radial* flexion. The surgeon stands with his body between the patient and the patient's hand, so that the blow cannot be anticipated. This blow causes pain in the wrist if the navicular is broken, while it does not if the hand is in ulnar flexion unless the lunate is broken. The percussion test is valuable in differentiation of navicular fracture and lunate fracture and dislocation. Tapping of the first and second metacarpals causes some pain in the wrist when the navicular is injured, but not so much as does that of the third metacarpal when the hand is held in radial flexion. The fourth and fifth metacarpals are not tender at all, because they do not transmit the force to the radius via the navicular and lunate bones. With the hand in ulnar flexion the pain is absent when the percussion test is applied for fracture of the navicular, but it is positive for fracture or dislocation of the lunate bone, though less in dislocation than fracture. Differentiation from sprained wrist lies in the greater area of soreness, which is quite evenly distributed about the wrist, and fracture of the radius is diagnosed by a swelling higher up and the tender styloids.

Sprain fractures of the radius, or injuries followed by a bursitis at the wrist or a synovitis in the sheath of the extensor carpi radialis brevis and extensor pollicis longus, are difficult to differentiate, as no ecchymosis may appear and there is a circumscribed swelling at the lower end of the radius which tends to spread upward. The tabatière is not tender.

The roentgenogram is needed to confirm the diagnosis. This should be taken of both hands on the same plate with the tube midway between them so that the question of bipartite bone can be answered at once.

Course and Prognosis.—If the condition is recognized at once and treated by immobilization, in fractures of the body without displacement of fragments bony union *may* occur. If the injury is not treated there remains rigidity and pain in the wrist, atrophy first of the hand and then of the forearm muscles, and persistent pain on pressure in the tabatière. In the intra-articular fractures absorption of bone follows from the action of attempted use and the constant bathing of the fragments by synovial fluid on their cancellous surface. The effort at callus formation is little or nothing, because most of the small nutrient vessels which enter the bone in the middle, the usual site of fracture, are torn, and as the cancellous surfaces have no periosteal covering, no union results; even fibrous union is rare. A pseudarthrosis develops. If a fragment is displaced to interfere with wrist motion, stiffness results from lack of use and the thickening

and changes induced in the wrist capsule. Small exostoses may develop from the radial surface into the joint capsule, or a bone atrophy or eburnation, with shrinking of all capsular structures. Use of the wrist is more and more restricted with lessened hand grip, constant pain, obliterated tabatière and an atrophic forearm.

Prognosis.—Prognosis of fracture of the tuberosity is good, as this is an extra-articular affair which heals in a short time, *with no interference with the wrist-joint.* There is a normal callus.

The final condition demands a year to be realized, and changes for the worse in unhealed cases of body fracture occur within that period. Blau studied 15 cases in soldiers and found that the loss of function equalled 33 per cent., but as he observed them only a few weeks he did not obtain final results.[1]

Treatment.—Tuberosity fractures, being extra-articular, are best treated by massage and passive motion. They should *not* be immobilized unless there is great pain and then for a few days only; use and motion must be insisted on, and heat should be employed.

Immediate treatment of body fractures depends on the displacement of fragments. If there is none, the hand is treated by immobilization for at least three weeks in a position of slight volar flexion, as this brings the fragments into closer apposition.[2] If a fragment is displaced on the dorsum, the wrist is acutely flexed, firm pressure is made on the back of the hand, and the joint is then completely hyperextended. If reduction fails by this method, Jones[3] advises immediate removal of the dislocated fragment or the whole bone. On the basis that few bony unions result, one seeks, by means of movement, use, and massage treatment, to establish a false joint. This obtains but poor results. Neglected cases which refuse operative treatment may be improved by the hand being fixed in hyperextension, with the use of a wrench if necessary, as the hand grip has been weakened because extension is limited, the power of the grip being greater in a position of extension. A case of fracture of the navicular with luxation of the lunate bone reduced by manipulation was reported by Skillern.[4] He made a reduction in accordance with the method of Codman and Chase,[5] and immobilized the wrist for four weeks without massage. The functional recovery was good, although it is not stated how long the patient was under observation and his criticism of Corner's case, seen eighteen months after a similar fracture, is not warranted. The latter's case after this period of time had greatly limited wrist motion, an obliterated tabatière, and a prominence over the distal part of the carpus.

The results of all methods of treatment lead to the conclusion that if a dislocated fragment cannot be reduced it should be excised at once (Figs. 338, 339, and 340).

[1] Deutsch. Ztschr. f. Chir., 1904, lxxii.
[2] Ehebald, Arch. f. Orthop., 1906, Heft 3.
[3] Proc. Roy. Soc. Med., England, December, 1910.
[4] Ann. of Surg., lviii, 716. [5] Ibid., xli, 321, 863.

Operative Treatment.—Old cases with stiffened wrists and restricted function, pseudarthrosis between fragments, with other bad end-results or persistent pain, should be operated upon.

FIG. 338.—Removal of a fractured navicular. The surgeon failed to notice that the lunate was dislocated.

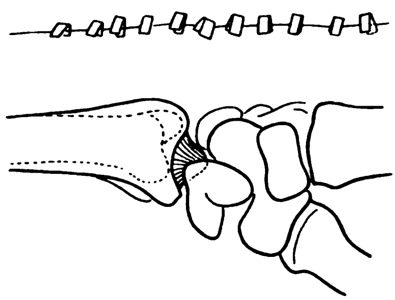


FIG. 339.—Side view of the preceding. Navicular removed and lunate present dislocated toward the palmar surface. Clips in skin wound on dorsum of hand.

No raw bone surface on a fragment should be left behind, and all fragments should be removed, especially in young adults or working people. Skillern[1] records one case treated by bloodless reduction and four weeks' immobilization with a good result. Hitzrot[2] removed the navicular and dislocated lunate bone in an acrobat who was enabled to resume his occupation without pain. Hirsch reports fifteen cases radically operated on, some of four years' standing, and all with very good results, and Wallace[3] one case with dislocation of the lunate, excision of which, with the proximal fragment of the navicular, gave a good hand. Another case recorded by Jaboulay,[4] was complicated by paralysis of the median nerve and atrophy of the thenar eminence caused by a dislocated fragment of the navicular. The paralysis had not improved much one and a half months after the removal of the bone.

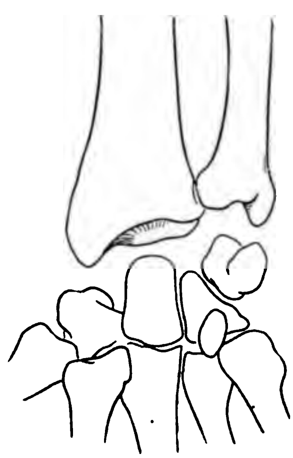


FIG. 340.—A second operation on the preceding for removal of the lunate. Both of the proximal row of carpal bones are now gone.

Technic of Removal.—The incision to approach the bone may be on the dorsal or palmar surface of the wrist, or on the

[1] Ann. of Surg., lviii, 716.
[2] Ibid., lii, 261.
[3] Lancet, March 22, 1913, p. 819.
[4] Lyon Med., 1913, cxxi, 699.

internal lateral side. The dorsal approach is the simplest. An inch long incision is made on the radial side of the wrist parallel to the border of the extensor carpi radialis, the tissues are retracted, the annular ligament is cut through between the extensor tendons with care not to open them or the bursæ, and the proximal fragment of the bone is cut down upon. A small hook is inserted between the fragments and they are pried or lifted out. The author believes both fragments should be removed. A suture of fine catgut may be put in the annular ligament, although it does not tend to gape, and the wound is closed tightly. After-treatment consists in immobilization for a week, followed by use and massage. If the fragment has been displaced forward, it can be reached through the palmar incision. It is never necessary to excise the whole proximal row of carpal bones in prompt operative care.

Lunate Bone.—Fractures of the lunate bone are often open, following severe injuries to the wrist. Closed fractures are caused by falls or direct violence, especially cranking or back-fire injuries, with the same mechanism as described in the navicular bone, the hand being held in ulnar flexion to transmit the violence through the lunate to the radius. Four cases were reported by Finsterer,[1] and he made a collection of 33 others. The physical examination is very unsatisfactory; the lesion may be suspected, but nothing is definitely known until a dried roentgenogram is studied. Percussion pressure on the middle metacarpal bone, the hand in ulnar flexion, the most reliable finding and pencil-point tenderness over the semilunar bone with no apparent displacement are symptoms. (See picture of the navicular bone.)

When the bone is crushed there is generally shortening of the carpus. This is demonstrated by observation and mensuration. The distance from the styloid of the radius to the head of the middle metacarpal is found shortened when compared to the other hand, and the surgeon may be able to see that the knuckle of the third metacarpal, which is always the most advanced and prominent, has been shortened, and lies on a level with the other metacarpal heads. The whole wrist may be thickened but not so much as in dislocation of the lunate bone, nor is there as much limitation of motion as in dislocation. Dorsal flexion is more interfered with than palmar flexion, but as the finger tendons are less displaced and pressed upon by a fractured bone than by dislocated lunate the function in the former condition is less affected. In dislocation also the median nerve may be pressed upon, and pain or trophic disturbances develop in its peripheral distribution. Fracture rarely involves the nerve.

The question of diagnosis and treatment of these lunate and navicular fractures is important from the standpoint of function and also for medicolegal reasons. We know that undiagnosed or untreated fractures of the wrist bones cause changes which may extend over a

[1] Beitr. z. klin. Chir., lxiv, 85.

period of years and end in stiffened wrists with functional loss. If the condition is diagnosed as sprain and use is continued, we may expect these late complications.

A condition known as isolated disease of the lunate bone has been noted. It is also called Kienböch's disease, after the first describer. A severe trauma to the hand and wrist does not seem to be essential, and the patient may forget that he injured himself, as he seldom stops work on account of it. Some time later pain and swelling appear in the wrist, accompanied by limitation of motion and loss of strength. A roentgenogram is generally taken at this time, the bone structure is observed to be less firm, the edges are crumbled away, and the whole lunate bone may be broken into two or three fragments (see Fig. 342). A question then arises whether the person suffered an injury at work and is entitled to damage under a compensation act, or whether the diseased condition of the bone has been caused by trauma which occurred outside of his work. Kienböch made careful examination of more than 1400 wrist-joints and concluded that the disease can occur without trauma severe enough to cause the patient to cease work at once. The pathology probably depends on interference with the blood supply which arrives at the bone via the ligaments. When a slight trauma is received the ligaments may be torn, the bone nourishment is interrupted, and the absorption begins. Primary fracture often causes the same results because of the impeded vascular supply and the poor osteogenetic properties of the bone. Consequently every case of wrist injury which involves workmen's compensation or employer's liability should be exposed to roentgenogram and carefully diagnosed. Becker[1] has added 20 cases to the literature, and he concurs with Kienböch's ideas. Frenkel-Tissot[2] reports 2 cases, 1 seen four and one-half years after an injury which had originally appeared to be a fissure across the radial epiphysis. Both of these cases had limited motion, with pain and tenderness in the wrist, and the roentgenograms showed irregular bone structure, flattening and decreased size of the lunate bone. A microscopic examination of 1 case showed a compression fracture following after the original nutritional disturbance of the bone.

As stated under navicular fractures, the lunate bone is more frequently dislocated than fractured, but as fractures of it are intra-articular, the results are much like those following body navicular lesions. Even in compression of the bone as recorded by Guye, 7 cases, Granier,[3] 3 cases, and Gaza,[4] 2 cases, the symptoms are much delayed and are probably caused by a slow process of bone atrophy and absorption from loss of blood supply, irritation, and the synovial fluid (Figs. 341 and 342). The persistent pain and loss of function coupled with the Roentgen-ray findings of lighter areas at the time of

[1] Beitr. z. klin. Chir., 1914, xciv, 172.
[2] Fortschr. der Röntgen Strahlen, 1914, xxi, 536.
[3] Deutsch. med. Wchnschr., 1909, p. 928.
[4] München. med. Wchnschr., Berlin, lxi, No. 41.

injury, or delayed secondary lime depositsand arthritic change make a diagnosis of fracture. Treatment of fresh fractures consists in immobilization of the wrist including extension of the third finger by straps or by a spring apparatus attached to the splint. Guye removed the bone early in two cases with good results. If the symptoms are latent for some time, a severe late secondary arthritis may develop which demands resection of the carpus. Operation is indicated in the face of these changes. The surgeon should be sure of the bone he is dealing with and make no mistake in removing the wrong one, or only a part of the damaged bone. This mistake happens, much to the chagrin of the operator when a roentgenogram is made later.

FIG. 341.—Recent comminuted fracture of the lunate bone.

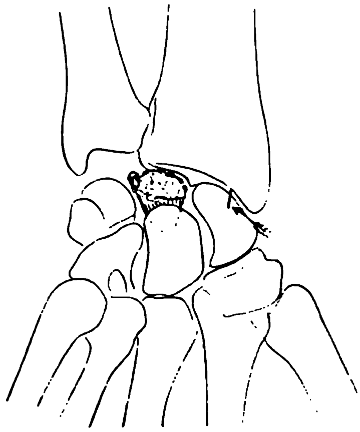


FIG. 342.—Old fracture of the lunate bone with absorption. The stiffness and disability in the wrist was supposedly caused by the piece of needle buried in it. The true trouble was exposed by the roentgenogram. Kienböck's disease?

Fracture of the Capitate Bone.—Glasmacher[1] found but one instance of fracture of this bone at the Cologne City Hospital in five years among twenty carpal fractures. Moty[2] says that the natural termination of these fractures is ankylosis of both the great wrist joints. A case was reported by Harrigan,[3] who states that there were but 5 cases in the literature, one only confirmed by the roentgenogram.[4] The cause is direct violence over the bone, or indirect violence applied to the heads of the second and fourth metacarpal bones sufficient to cause sudden flexion of the wrist. If the posterior radiocarpal ligament is weak, a blow of this character results in a posterior wrist dislocation; if the ligament holds, the strain is exerted on the neck of the relatively immovable capitate bone, the head of which by rotation transmits

[1] Inaug. Disser., Leipzig, 1906.
[2] Gazette des Hôpitaux, 1890, No. 69.
[3] Ann. of Surg., xlviii, 917.
[4] Guermonprez-Monjaret Jour. d'Sci. Med. de Lille, 1904, xxvii.

force from the metacarpals to the carpal bones, and fracture results. The symptoms are pain in the carpus, swelling over the bone, especially on the dorsum, loss of function in the hand, and localized tenderness. If the head is dislocated out of its position, it can be felt beneath the skin.

Treatment.—Treatment consists in complete immobilization of the hand for three to four weeks. Excision is necessary for dislocated fragments or persistent symptoms. Destot[1] said he had seen three cases but gave no details.

Fracture of the Triangular Bone.—Isolated fracture of the triangular bone is rare. Coues[2] reported a case in a woman, aged twenty-three years, who was standing on her hands in a gymnasium. She lost her balance and fell over, rolling on her left hand, which was flatly extended on the ground. Immediate pain and loss of function occurred, and she asserted that crepitus was present. Ecchymoses appeared with pain in the wrist, and lateral pressure against the pisiform caused transmitted pressure on the triangular with resulting tenderness. Immobilization on a palmar splint gave relief and bony union after two months.

Fracture of the Pisiform Bone.—The pisiform is rarely fractured. The author has seen one case, an extra-articular crack which healed promptly. Deane[3] reported a case in a man aged twenty-three years who fell down an elevator shaft. The mechanism was hyperextension of the wrist-joint with the hand adducted. The pull of the flexor carpi ulnaris was strong enough to cause a transverse fracture of the bone with the counter pull furnished by the ligamentous attachment to the triangular bone. There was crepitus on manipulation, and the roentgenogram confirmed the diagnosis. Other symptoms are pain in the bone when the flexors are contracted and local tenderness on pressure. Lesions of the bone which open the wrist-joint or which divide it in an axis parallel to the palmar surface may not result in bony union, for reasons expressed under the discussion of the navicular bone.

Fracture of the Multangular and Hamate Bones.—The multangular and hamate bones are also rarely fractured. The author has seen one fracture of the greater multangular bone in connection with fracture of the navicular.

FRACTURES OF THE METACARPAL BONES.

These fractures are common, though not so frequent in hospital records because the patients do not remain there. Stimson quotes some figures from Paris hospitals before the Roentgen-ray period, which place their frequency about 1.12 per cent. In the 10,702 fractures reviewed at the Cook County Hospital there were 208 fractures

[1] Verhdlg. d. Deutsch. Roentgen. Ges., 1905.
[2] Boston Med. and Surg. Jour., clxx, 579.
[3] Ann. of Surg., liv, 229.

of the metacarpal bones, nearly 2 per cent. Epiphyseal separations are found in these bones, as in other long bones, and are more frequent than was believed before the Roentgen-ray examination became routine in injuries. Coues,[1] in 1912, asserted that there are but 2 cases of epiphyseal separation of the first metacarpal as described by Poland,[2] and he added another in a fourteen-year-old boy. Others have been recorded by Sturrock,[3] 1 case, and Gasne[4] 2 cases of the first and 4 cases of the other metacarpals. In the thumb there is usually but one epiphysis, at the base of the metacarpal bone, a fact which has led to discussion of the character of this bone and the possibility of its really being a phalanx. The other four metacarpals have epiphyses only at the heads of the bone. Epiphyseal separation of the first metacarpal is different from the so-called Bennett's "stave" fracture (see Figs. 343 and 344)[5] which is an oblique fracture of the

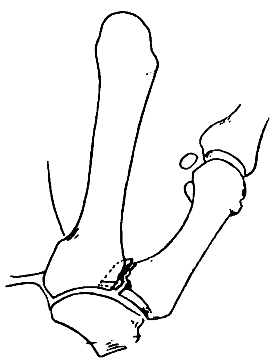


Fig. 343.—Bennett's fracture of the first metacarpal—thumb.

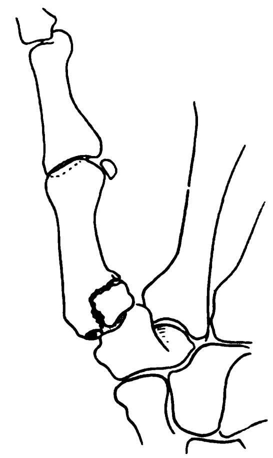


Fig. 344.—A different type of Bennett's fracture of the thumb metacarpal.

proximal end, the palmar fragment opening into the joint and the distal portion being separated and dislocated backward to a varying degree. The lesion simulates a dislocation of the thumb, and differential diagnosis is usually determined by Roentgen examination. Many of the Bennett fractures are not more than a crack, sometimes received in blows on the thumb joint direct, or by an unexpected abduction. Rarely the bone is comminuted clear through the thickness of the shaft, and there is considerable displacement of the fragments. The causes are direct and indirect violence. One may incur the injury from blows of the fist, sudden falls with a slapping of the back of the

[1] Ann. of Surg., lvi, 450.
[2] Traumatic Separation of the Epiphysis, 1898, p. 588.
[3] Edinburgh Hosp. Repts., ii, 603.
[4] Rev. de Orthop., March, 1913.
[5] British Med. Jour., July, 1886.

hand against the ground, squeezes of the hand by being caught between heavy objects, direct pressure from suddenly applied heavy weight when lifting large objects, and slipping. Indirect violence of a torsional character may also cause these fractures. The bones most exposed to external violence, the first, second, and fifth, are naturally the ones most frequently injured. The middle bones are sometimes broken by indirect violence from the twisting of a finger, or a fall on an outstretched finger.

Symptoms and Diagnosis.—Swelling of the hand may mask the findings on examination. Severe pain on pressure over the bone or bones injured, when the corresponding fingers are extended or pressed toward the carpus, is sufficient evidence to warrant treatment as fracture. There may be false motion, and crepitus is almost always present, coupled with loss of function in the fingers. The roentgenogram will frequently reveal more than one bone broken (see Fig. 345).

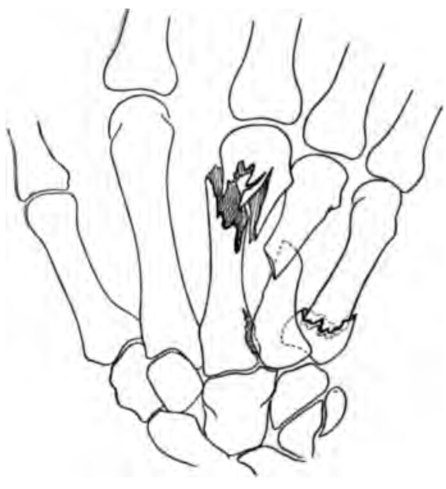


Fig. 345.—Multiple fractures of the metacarpal bones.

Fig. 346.—Fracture near base of the second metacarpal

Displacements are not great on account of the muscles and the proximity of the bones (see Fig. 346). Near the head the distal fragment is usually displaced toward the dorsum and may override laterally, so that dislocation of the finger backward must be differentiated. In the thumb, if there is a luxation at the base, the metacarpal is always displaced posteriorly, and the distal part is in flexion. If the fracture is crack-like, there may be no displacement, and epiphyseal separations differ in that the displacement is generally lateral instead of posterior, there is a muffled crepitus, and a greater tendency for the recurrence of deformity after reposition. The luxations of the other four fingers usually cause a hyperextension of the first phalanx and flexion of the last two, while in the epiphyseal separation all three phalanges are in extension. White, in Piersol's *Anatomy*, described a

disjunction of the epiphyses of the fourth and fifth metacarpal bones in a lad aged fourteen years. This is a rare injury, because the metacarpals of the index, middle and ring fingers are longer and subject to greater trauma.

Union between fragments is generally complete in one month. Occasionally an angularity persists, or the callus may adhere to a tendon, giving a stiff and partly extended finger in the metacarpo-

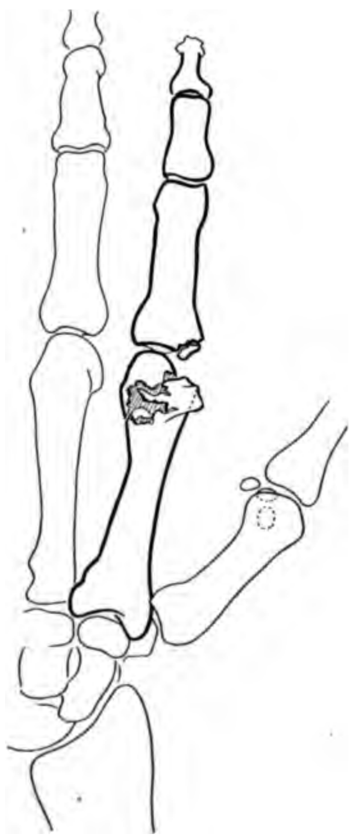


Fig. 347.—Fracture near the head of the second metacarpal. The phalanx has also been chipped.

Fig. 348.—Fracture near the head of the fifth metacarpal.

phalangeal joint. If two neighboring bones are broken, they may become united together and impair the hand function. Non-union is extremely rare, and the usual result is satisfactory from a functional standpoint.

Treatment.—Many of these fractures are open. If they are closed there is always swelling and edema of the hand and fingers, which is painful and throbbing in character. This demands first attention and is cared for by alcohol dressings and maintaining the hand in

an elevated position or by the application of an ice-bag. Fractures with little displacement are treated by a small and well-padded palmar splint extending from the finger bases and above the wrist. If extension of the finger corrects the deformity, the finger of the bone involved may be held in that position by the same splint. If possible, the fingers should be left free for movement to avoid stiffness. The palmar splint may be strapped on by adhesive which runs across the dorsum

Fig. 349.—Pathological fracture of the fifth metacarpal. The thumb and wrist have also been invaded by the carcinomatous process. Case of Dr. D. D. Lewis.

of the hand and helps hold the fragments in position. Fractures of the second and fifth bone should not be bound on to a palmar splint by a roller bandage, as this tends to cause lateral displacement. Plaster-of-Paris encasements are also used after the initial swelling is gone, as they provide secure protection to the hand from knocks through its brushing against objects.

Fractures near the head of the outer four metacarpals give trouble-

some displacements and are difficult to hold in reduction (Figs. 347 and 348). A ball or a wad of padding placed in the palm makes an admirable dressing, the hand being strapped on it. The position of the fingers in flexion pulls the metacarpal joint at the finger base into position. Extension placed on the finger by adhesive fastened to a spring dressing on a palmar splint may reduce the deformity, but the finger joints do not tolerate this type of dressing very well. Rarely operative interference may be indicated for cosmetic or functional reasons. Simple reposition of fragments is the best method, approach being made on the dorsal side of the hand. Wiring has little value over reposition, as the wire often fails to hold the adjustment if the fragments will not remain in position by replacement and splinting. An extra epiphysis sometimes appears at the base of the second metatarsal. It may be separated. I have seen one case incidentally discovered in the roentgenogram. Skillern[1] has recorded a case.

Bennett's fracture requires special treatment. If there is little displacement, the thumb is held in slight abduction by a plaster spica encasement run down onto the hand, to protect it from movements or jars while healing. If displacement is greater, traction may be maintained in abduction by an adhesive extension applied to a splint fastened to the palm or buried in an encasement on the hand. Generally traction on the thumb with pressure inward at the base affords a satisfactory reduction, and a plaster spica or palmar splint holds the reduction. This should be left on about three weeks and motion then started (Fig. 349).

FRACTURES OF THE PHALANGES.

The phalanges are broken by direct or indirect violence in crushings or gross injuries of the hand and fingers, or in squeezes between heavy objects. Many are open fractures and must be dealt with accordingly. Indirect violence causes fracture in twisting of one or more fingers or sudden hyperextension, as in falls and pushes or baseball injuries.

The proximal phalanx is most frequently broken, and the displacement is usually not great, as the line of fracture tends to be transverse. Comminution in direct violence occurs, and small lines of fractures may be evident in the roentgenogram which are not anticipated clinically (Fig. 350). The author has had one case of oblique fracture from palmar to dorsal surface in the distal phalanx of the little finger of a heavy woman. This was caused by her catching the finger on the casing of an automobile door as she was getting out, her momentum carrying her forward and causing her whole weight to be suspended by the end of the little finger.

Symptoms and Diagnosis.—The symptoms are pain, false point of motion in the continuity of the phalanx, and crepitus, which can always be felt if there is complete fracture. Diagnosis is easily made.

[1] Ann. of Surgery, March, 1915, p. 374.

Each phalanx of a finger can be taken delicately between the index finger and thumb of each hand and carefully rocked for evidence.

Bony union is the rule if the fracture is not open and infected. Hartmann[1] recorded a case of non-union with deformity after fracture of the proximal phalanx of the thumb treated for six weeks on a card-board splint. He freshened the fracture plane by operation and obtained a good result. If infection sets in, the finger should be widely opened and ample drainage provided, and the bone early removed in its entirety, leaving periosteum behind for regeneration. The finger will shorten after this procedure, if it is not held in extension, but the suppurative process stops quickly. The distal *phalanx* should be removed at first evidence of osteomyelitis following its fracture—it does not regenerate. Long-continued suppuration and drainage often lead to amputation. Secondary amputation may be done later to

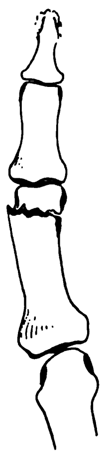


Fig. 350. — Transverse fracture of the proximal phalanx of the index finger.

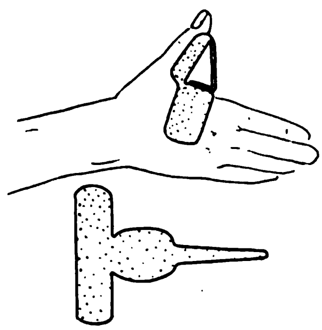


Fig. 351.—Goldthwaite's thumb splint cut out of sheet metal and folded to fit thumb.

get rid of a contracted and deformed finger which is stiff and really interferes with hand function. In the case of the thumb, every effort should be made to preserve all of it.

Treatment.—With no displacement the finger may be strapped to its fellows in extension, and union will be prompt (Fig. 351). Strapping is removed completely in two weeks. Padded wooden tongue depressors make good splints for fractures of the two distal phalanges. Such a splint can be fixed to the palm by strapping and the finger lightly bandaged on. The splint should be extended *beyond* the end of the finger to ward off all jars. Various extension dressings made by applying adhesive tape spirally to the finger distal to the point of fracture have been devised. These are valuable in fractures of the proximal phalanx.

[1] Ztschr. f. orthop. Chir., 1914, Bd. xxxiv, Heft 3–4.

The interossei muscles tend to flex the proximal phalanx in extending the distal two, and their action causes a forward displacement of the proximal fragments in fracture of the proximal phalanx. This results in an angularity, directed forward, which may interfere with the hand grasp. These fractures are best treated by flexing the fingers over a roller bandage, or a round soft palmar mass, and fixing them in position by adhesive tape or a roller bandage. This position relaxes the interossei and takes advantage of the pull of the extensor tendons to help correct the deformity. Molded plaster of Paris may be similarly applied by one cutting out thin strips of the wet material with a sharp knife and bandaging them on in any desired position.

Fracture of the sesamoid bones of the thumb have been reported by Preiser[1] and Morian.[2] These do not tend to heal by bony union, and have little significance if they do not interfere with flexion. Bipartite bones must be excluded. The author has seen a roentgenogram of one case long after trauma in which a small fragment was detached and probably partly absorbed.

[1] Aertzl. Sachverst., 1907, p. 400.
[2] Zentralbl. f. Chir., 1910, p. 423.

CHAPTER XX.

DISLOCATIONS OF THE WRIST, HAND AND FINGERS.

1. Dislocations of the Lower End of the Ulna.
   (*a*) Backward.
   (*b*) Forward.
2. Dislocations of the Lower End of the Radius, Radiocarpal Dislocation.
   (*a*) Backward.
   (*b*) Forward.
3. Mediocarpal Dislocations and Fracture Dislocations.
4. Isolated Dislocations of the Carpal Bones.
5. Carpometacarpal Dislocations.
6. Metacarpophalangeal Dislocations of the Finger and Thumb.
7. Phalangeal Dislocations of the Thumb and Fingers.

The luxations of the lower radio-ulnar joint are confusing and the literature on the subject is misleading. The Roentgen rays have furnished a modern classification which is exact. In the past many so-called wrist dislocations were examples of the different types of Colles's fracture with the varying displacements and complications. This is particularly true of so-called inward dislocations of the lower end of the ulna, which are not true dislocations but are simulated by the outward displacement of the lower end of the radius and the wrist in Colles's fracture. The remaining dislocations of the ulna backward and forward are recognized as true luxations. In 1912 Stimson collected 22 undoubted cases of forward and 15 of backward dislocations of the ulna.[1]

DISLOCATIONS OF THE LOWER END OF THE ULNA.

Backward.—The backward luxations are not common when the number of wrist injuries are considered. The causes are twisting strains which turn the hand in hyperpronation and falls on the hand in pronation and adduction. Children are often subjects of this luxation, and the condition may accompany the subluxations of the radial head which are caused by longitudinal traction. These subluxations in children may be complicated by wrist pain and slight deformity consisting of a prominence of the lower end of the ulna backward (Fig. 352).

Symptoms.—The hand is in some pronation and adduction, and there is loss of function in the wrist and fingers. Wrist flexion and

[1] Fractures and Dislocations, 1912, 7th edition, p. 747.

extension are possible passively, but supination is restricted. The wrist appears narrowed, and the lower end of the ulna rides backward and overlaps slightly the radial margin. In recent cases the lower end of the ulna is abnormally movable, and its projection may be partly reduced by direct pressure. Differential diagnosis must exclude

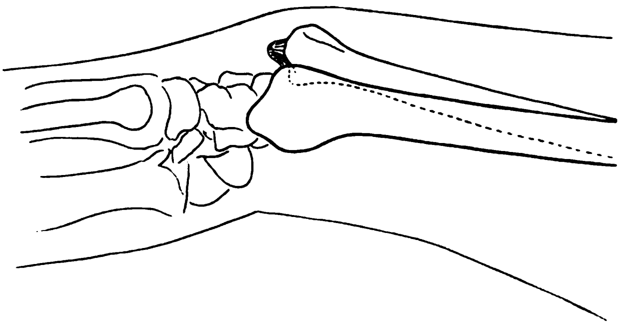


Fig. 352.—Backward dislocation of the lower end of the ulna.

Colles's fracture, dislocation of the semilunar, and Madelung's deformity. The position of the radial styloids, the history in the congenital deformity, and the roentgenogram afford a basis for distinction of these conditions (Fig. 353).

Treatment.—Reduction is made by direct pressure on the projecting part of the ulna, usually by the surgeon's thumb, both his hands grasping the wrist above the deformity. He makes a strong pressure downward and outward to shove the ulna back into position, and the reduction may occur with a jerk as the lower end of the bone

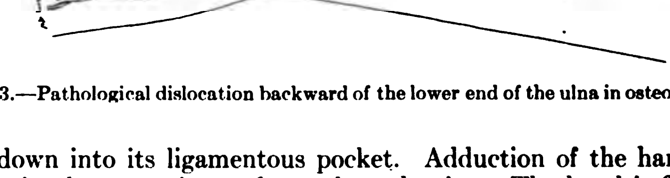


Fig. 353.—Pathological dislocation backward of the lower end of the ulna in osteomyelitis.

slips down into its ligamentous pocket. Adduction of the hand and supination by an assistant favor the reduction. The hand is fixed in position of supination in a moulded plaster splint, kept there for four or five weeks, and pronation cautiously started thereafter. Fracture of the ulnar styloid may prevent reduction, but usually the detached bone fragment is pulled medially and bent around under the ulno-

carpal joint by ligamentous attachment. Long-standing cases have been reported as reduced by manipulation. One old case which I saw resisted all attempts at reduction, and because the hand function was lessened and supination was lost excision of the lower end of the ulna was advised. After long-standing changes in the tissues below the lower end of the displaced ulna it is not possible to hollow out the normal cavity in which the bone lay, and reduction with open operation becomes very difficult. If the end of the bone can be reduced, it tends to slip out of place again very easily and must be held by stitching of the ligaments found over it, or by a band of transplanted fascia applied to act as a stay.

Results after reduction are good. Function becomes satisfactory, supination alone being lessened slightly. In the old traumatic cases which remain unreduced, more or less permanent loss of use remains. The hand is weakened, and a firm cicatricial mass encloses the dislocated end of the ulna.

Dislocations Forward.—Of this type of dislocation there are 33 cases on record. The condition was first described by Desault, in 1791,[1] who found the dislocation in the cadaver of an old man.

The causes are usually direct violence which twists the wrist in forced supination; 7 cases were caused by this action, 1 case by forced pronation. A direct backward shove on the hand when the ulna is fixed mechanically, as in back-fire injuries in automobile cranking may be a cause; and muscular contractions of the triceps when the hand is fixed has caused 3 cases. The lesion consists of a forward and slightly outward displacement of the ulna after its ligamentous attachments have been torn loose. The radius may be fractured in the lower third,[2] or the ulnar styloid may be pulled off.

Symptoms.—The symptoms are loss of function in the wrist with varying positions of pronation and supination. The hand and radial side of the forearm are displaced backward from the ulna, which is displaced forward with some overlapping of the radius. The motions of the fingers are partly interfered with, and there is swelling in the wrist which appears narrowed, but is thickened in the anteroposterior diameter. The characteristic finding is the hard, round end of the misplaced ulna beneath the flexor tendons just above the palmar crease and a hollow space on the back of the wrist where the bone should lie. Every case must be carefully examined for possible accompanying fracture of the radius.[3]

Treatment.—Reduction is not easy to perform. The injured hand is grasped and traction made on it in radial flexion, while the head of the bone is pressed back into place by an assistant, the hand and wrist being turned in either extreme supination or pronation, depending

[1] Jour. de Chir., i, No. 1, 78.

[2] Darrach, Ann. of Surg., lvi, 801.

[3] Stimson, New York Med. Jour., May 25, 1889; Holst, Centralbl. f. Chir., 1889, No. 24, p. 495; Lewen, Centralbl. f. Chir., 1906, No. 24, p. 1128; Hoffa, Verhandl. d. deutsch. Gesellsch f. Chir., 1898, p. 156; Corntin, Gaz. hebd. des Sci. Med. de Bordeaux, October 8, 1905, p. 481.

on the character of the displacement. Luxation is generally reduced with the fracture, if there is radial fracture, and heals with it. If the ulna remains out of place it is the result of rupture of the triangular ligament, and the ulnar head becomes mobile as the joint ligament relaxes. A roentgenogram should be made for checking purposes after the reduction and the splint should be left on at least three weeks. If reduction cannot be accomplished the distal inch of the bone can be excised, as in a second case reported by Darrach.[1] The patient was a thirty-four-year-old man whose hand had been caught in a machine belt a month and a half before being seen. The hand was twisted into extreme pronation. There was pain in the wrist, pronation and supination were about one-third normal, extension was normal, but flexion was limited to one-half, and the fingers were also limited in motion. The median and ulnar nerves showed no involvement. One-half inch above the palmar crease the head of the ulna could be felt in forward dislocation. Reduction by manipulation was impossible, and the lower inch of the ulna was resected subperiosteally, and after two weeks massage and motion were begun. After five weeks the patient resumed his occupation. Osteectomy is the treatment of choice in unreduced cases or old cases with limitation of movement and of use of the wrist. Cotton and Brickley[2] advise that end-results are good after prompt reduction in fresh cases. Hitzrot[3] reduced an anterior dislocation by flexing the wrist and turning it into full supination and radial flexion. After fifteen months the function was perfect, and there was no pain. In general the outlook is not bad because function may not be greatly reduced by non-reduction.

Recurrent luxation of the ulna has been described by Cotton,[4] who mentions 2 cases; 1 followed a Colles's fracture, and the other was accompanied by ulnar neuritis with a slipping out of the ulna on every movement of supination. An extreme laxity of the wrist ligaments was the probable cause, and one case was cured by osteotomy, which had the effect of tightening the radio-ulnar ligaments.

Darrach[5] has also reported an habitual forward dislocation of the lower end of the ulna. There had been a radial and ulnar styloid fracture caused by an automobile-cranking accident eleven months before the patient was seen and a refracture within three months. Six months after the second fracture when the patient was thrown and hurt the wrist again, he felt something slip out of place at the ulnar head. There was a widened wrist, a silver-fork deformity, and decreased power. When the hand was pronated the ulnar head could be felt to slip back into place and the ulna was not separated laterally from the radial connection.

Madelung's Deformity.—Although this work does not attempt to deal with congenital deformities a brief description of Madelung's deformity must be given to help differentiation between the traumatic

[1] Ann. of Surg., 1912, lvi, 802.
[2] Ibid., lv, 368.
[3] Ibid., 623.
[4] Dislocation and Joint Fractures, p. 364.
[5] Ann. of Surg., lvii, 928.

and congenital deformities at the wrist. Dupuytren, in 1834, first described a condition which he called a unilateral forward dislocation of the ulna, and in 1878 Madelung[1] described it as a progressive curvature of the radius which developed spontaneously, and was accompanied by pain and disability. Adduction and abduction of the wrist are not greatly limited, but extension of the wrist is. There is an atrophy of the carpal bones and cartilages, the epiphyses of the ulna and radius take on an atypical growth with an hypertrophy on the dorsal side, and the diaphysis of the radius is curved anteriorly with a dislocation backward or forward of the ulna. Most cases occur in adolescents of the working or the poorer classes who show evidence of rickets or tuberculosis. Stetten, in 1908, collected 62 cases.[2] Females are more affected than males. Most instances have been forward dislocation of the ulna, only 2 or 3 being backward.

Pathology.—The pathology is undecided, but probably rests on a late rachitic deformity involving the growth of the lower radial epiphysis with a primary deviation of the articular surface forward or backward, the direction probably influenced by the repeated trauma of occupation. There is possibility of an unrecognized epiphyseal separation of the radius acting as a cause. One of Stokes's cases[3] might be interpreted as of such an origin. The patient was a fifteen-year-old girl who gave a history of heavy weight-lifting two years before. She had slight signs of rickets at the fifth costosternal junction, and both tibiæ bowed outward. The skull was normal.[4] Evidence also points toward the imperfection of the joint cartilages in the carpus. They are ossified in some areas and irregularly thickened in others. The epiphyseal ends of the forearm bones are not completely developed, and they are excurvated or club-shaped, so that they do not hold the carpal bones in place on the volar side. Franke[5] does not consider the condition a true dislocation, but favors the idea that there is a deviation of the wrist axes caused by the curve in the radius. There are also changes in the carpal bones, which are atrophied, and there is relaxation of the wrist ligaments. The whole condition has been likened to the changes in genu valgum or scoliosis. Recently Berg,[6] reporting 3 cases, has made a plea for the application of the term carpus valgus to these wrist deformities regardless of their etiology.

Symptoms.—The symptoms are a spontaneous and progressive deformity of bowing in the radius with an accompanying dislocation of the lower end of the ulna. There is pain and limitation of wrist motion, and in 2 or 3 years the deformity reaches its height, accompanied by weakness, constant pain in the wrist, and restricted motion. There are usually signs of delayed rickets and possibly auto-intoxication, alcoholism, syphilis, or tuberculosis (Cantas's case). When the

[1] Verhandl. d. deutsch. Ges. f. Chir., vii, 259.
[2] Zentralbl. f. Chir., 1908, xxxv, 949.
[3] Ann. of Surg., lii, 229.
[4] Cantas, Lyon Chir., 1913, x, 434.
[5] Deutsch. Ztschr. f. Chir., 1908, xcii, 156.
[6] Arch. f. Orthop. Mechanotherap. u. Unfallchir., 1913, xii, 325.

diagnosis is made these various conditions must be excluded by a careful general examination and by roentgenogram.

Treatment.—Many different treatments have been used in the 80 or more cases recorded in the literature. The disease generally reaches a maximum deformity within three years after its inception, and radical treatment is not indicated except for cosmetic reasons, because the prognosis of functional result in adult life is good. When the deformity becomes stationary, surgical operation alone will effect a cure. Tenotomy has no value. A linear or cuneiform section of the radius done at the point of greatest curvature will correct the bowing of the bone, but this may not influence the dislocated head of the ulna if permanent changes have occurred about it. Function improves after the operation. Parkes[1] has reported a case in which he sectioned the radius and applied a small Lane plate which was removed six months later after the deformity was greatly improved. Cantas resected 1.5 cm. of the diaphysis of the ulna 4 cm. above the styloid process and then straightened the radius by manual fracture and sutured the ulna. A plaster cast was applied for thirty days, and the functional result was perfect, the radiocarpal articular surface resuming a normal position, but the ulna did not contact with the carpal bones and continued to project at the wrist. Stokes believes that osteotomy is not indicated, but that rest and proper diet will gradually cause the deformity to disappear after the patient reaches maturity (age of twenty-five years). The silver-fork deformity persists. To obtain the best cosmetic and functional result Springer's advice may be taken.[2] His procedure is (1) division of the pronator quadratus; (2) osteotomy of the radius about 1½ inches above the joint; (3) resection of the prominent part of the end of the ulna; (4) complete supination of the forearm by twisting, with dorsal flexion and abduction of the hand; (5) a plaster cast from the middle arm to the finger ends with the elbow flexed. After two weeks the palmar half of the cast is cut off and massage and movements are commenced.

MEDIOCARPAL DISLOCATIONS AND FRACTURE DISLOCATIONS.

Carpal Dislocations.—The subject of wrist dislocations has become one of much interest since the roentgenogram has aided us in explaining the intricacies of wrist displacements and the position of the small bones after luxation. The reader is referred to description of the relation of the wrist bones given previously in the discussion of fractures of the carpus. The wrist evidently is composed of three elements which may be concerned in fracture and dislocation. The radius and ulna, the first element, are very firmly united by ligaments to each other and to the second element, which is com-

[1] Ill. Med. Jour., 1915.
[2] Ztschr. f. orthop. Chir., xxxiii, Heft 34.

posed of the proximate row of carpal bones, navicular and os lunatum. The proximate carpal bones are in turn united to the distal row by ligaments which permit motion in this joint, the mediocarpal and the distal bones are practically immovable as units on account of the firm banding together by interosseous ligaments.

Dislocations of the hand and wrist may be grouped as (1) Dislocations in the radiocarpal joint; (2) dislocations in the intercarpal joint between the two rows of carpal bones; (3) dislocations in the carpometacarpal joint.

Mechanism of Wrist Movements and Injuries.—Radiocarpal dislocations are not frequent and are usually accompanied by fracture of one or both forearm bones. They are caused by violence, direct or indirect in character. Displacements are either backward or forward. Sievert[1] has reported an instance of volar luxation of the radiocarpal

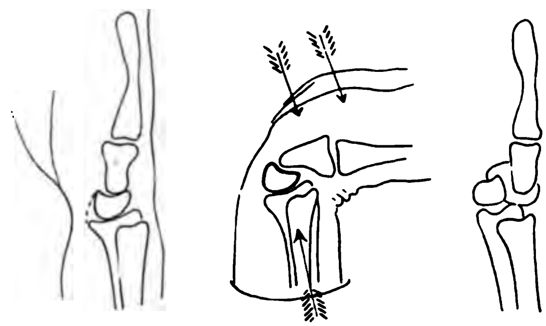


Fig. 354 Fig. 355 Fig. 356

Figs. 354, 355, and 356.—An illustration of a mechanism for intercarpal dislocations, adapted from Oehlecker.

Fig. 354.—Shows a normal hand with the bone line from metacarpal, os capitatum, lunate and forearm bones. The radiocarpal volar ligament is indicated.

Fig. 355.—Shows hyperextension of the hand, lunate and os magnum each contributing 45 degrees to the angle of 90 degrees.

Fig. 356.—Lunate luxated, held in nearly normal position by the radiocarpal ligament. The hand is in perilunar dorsal dislocation.

joint from Kolliker's clinic. The lower radial and ulnar surfaces were fractured. The patient was a fifty-year-old man who sustained a fall on the back of the hand. Diagnosis was easy and reduction was also, but the wrist sank back into displacement immediately after support was removed.

Experiments in wrist movements performed by Codman[2] in 1898 showed that there was no motion between the individual bones of the distal row of the carpus. Flexion and extension of the wrist occur entirely in the joints proximal and distal to the first row of carpal bones, and the variation from complete extension to complete flexion of the hand, 180 degrees, is possible by movement of each of these joints through 90 degrees. This is illustrated in Figs. 354, 355 and 356,

[1] Zentralbl. f. Chir., 1910, p. 1129; München. med. Wchnschr., 1910, No. 16, p. 849.

[2] Jour. Exper. Med., iii; and Boston Med. and Surg. Jour., cl, No. 14, p. 371.

which shows the probable mechanism of mediocarpal dislocations. It is seen that in complete extension shown here, the os lunatum and the os capitatum are each rotated 45 degrees from each other's perpendicular axis; the total angulation brings the axis of the os capitatum at 90 degrees variation from the long axis of the radius. In flexion

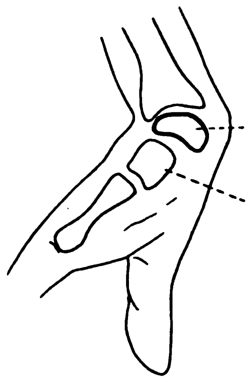


Fig. 357.—Hand in hyperextension. Lunate and os capitatum each contributing 45 degrees of angulation.

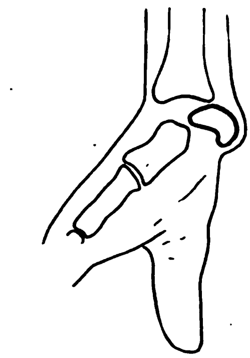


Fig. 358.—Lunate slipping out, held to radius by radiocarpal ligament.

the same principle applies. Codman and Chase[1] called attention to this in 1905, and suggested that if the wrist were looked at from the side, in complete flexion, the axis of the lunate bone would point at an angle of 45 degrees to the vertical axis of the radius, and the long axis of the capitate bone, which formed a continuation of the meta-

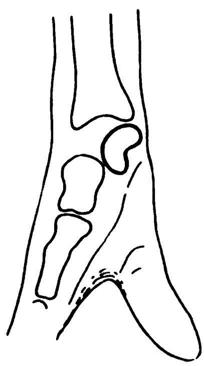


Fig. 359.—Os capitatum approaching radius again. Lunate squeezed out.

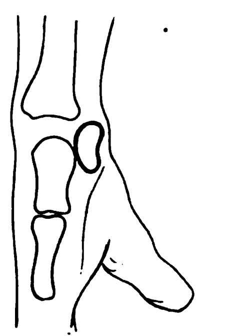


Fig. 360.—Volar dislocation of the lunate.

carpal axis, would add another 45 degree variation. Consequently the axis of the capitate bone would lie at an angle of 90 degrees with the radius. This axial variation in dislocation may be illustrated as in Figs. 357, 358, 359, and 360.

[1] Ann. of Surg., xli, 863.

Because of their firm ligamentous attachment and their position protected by the styloid processes, the two proximal carpal bones tend to remain with the radius and ulna in displacements at the wrist. In the discussion of fracture of the navicular and lunate bones of the wrist we have seen that the cause of most of the lesions was a fall on the extended hand, the resulting fracture depending largely on the position in ulnar and radial flexion. Violence is transmitted through the third metacarpal and os capitatum to the radius directly and if the hand is in radial flexion the navicular bone suffers fracture, the usual occurrence. If the hand is in ulnar flexion, the lunate bone is brought over into the line of compression and is damaged. The mechanism of dislocation is very similar except that the hand is bent back in hyperextension and not held rigidly in a straight position with the long axis of the radius, as it is in most cases when a man falls forward on his hand and attempts to save himself. With the hand in hyperextension, force is applied as illustrated in Figs. 354, 355 and 356 (from Oehlecker), and the lunate bone and os capitatum, which have already reached their maximal rotatory excursion of 45 degrees each, are called upon to take up the strain of the fall. Habitual strain or occupation may bring about a condition of subluxation of the carpal bones. Relaxed ligaments and the bone construction favor the condition. An instance of diastasis of the navicular and lunate bones has been reported by Layorenne.[1] His patient was forced by his occupation to use his hand in hyperextension and he developed signs of arthritis in the wrist. A roentgenogram showed a separation between the navicular and lunate bone, and recovery resulted after a period of immobilization. Direct violence on the hand may also cause carpal dislocations.

As in all joint injuries the surgeon must be on his guard against pathological dislocation. Destot and Japlot[2] reported an injury to a young man who sustained a slight fall on the left wrist. There followed persistent pain, deformity, and swelling, although the hand had been immobilized at once, and ultimately a pathological subluxation of the second carpal row forward caused by a tuberculous condition was recognized.

In Runyan's report of 8 cases in the Canal Zone at the Ancon Hospital, the total number of admissions to the hospital in six years had been 120,000. In 5 of the 8 instances the left wrist was injured. The men employed there were all exposed to trauma. One-half the cases were caused by indirect violence of falls and the other half by direct violence of blows. Fracture of these bones does not result because there is not direct compression of them, but the joining ligaments must take up the force and hold, or if they yield a dislocation will surely result. A point is reached in the pressure of hyperextension where the posterior ligaments uniting the lunate and capitate bones are stretched, where the os capitatum begins to slide backward on the

[1] Soc. de Chir. de Lyon, June, 1913. [2] Ibid.

lunate, the anterior ligament between the two bones is made to bear most of the strain and yields, permitting the os capitatum and its closely bound distal row of carpal bones to be dislocated backward. The navicular may accompany them, especially if the hand is in ulnar flexion. The line of dislocation passes through its body, following the line of least resistance through the mediocarpal joint, a fracture of the navicular occurs, and the proximal fragment is displaced with the os lunatum. Mouchet and Vennin[1] record a case of a patient who fell from his horse on to his hand and was treated for nine months for a fracture of the radius. They found a well-marked deformity with a dislocation of the carpus into two parts displaced over each other. The navicular was fractured in the middle, one-half going with each row of carpal bones. Meanwhile the os lunatum (and the broken proximal portion of the navicular) cling closely to the radius and ulna, as we have previously stated, held by the strong unruptured radio-ulnar ligaments. The os lunatum may not rotate, but may retain a

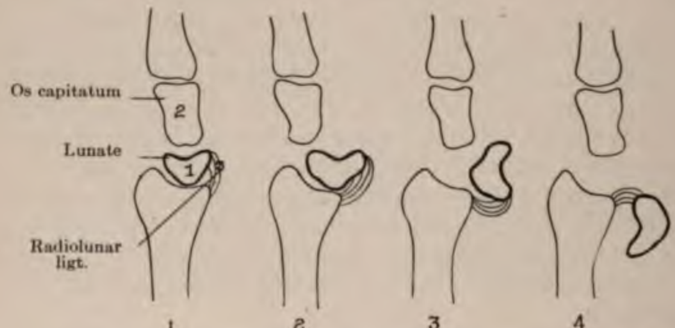


FIG. 361.—Lateral view of lunate dislocation adapted from Vulliet.

normal axis line with the radius after this luxation, and this condition has been called *perilunar dorsal dislocation of the hand* (see Fig. 356). When, however, the force continues and the hand is pushed farther dorsally, the os capitatum is hooked over behind the lunate and this compression drives the lunate toward the volar side and the bone is swung downward, usually assuming an angular position of 90 degrees (see Fig. 361) with the radius, being held attached to it by the radio-lunate ligaments. Its concave surface is directed forward. This state constitutes a complete volar dislocation of the lunate bone and is the second stage of the mechanism given above. The two conditions of the perilunar dorsal dislocation of the hand and volar dislocation of the os lunatum are not exactly the same but differ in degree. In 6 cases of lunate dislocation Oehlecker[2] found that 2 were volar dislocations and that 4 should be classed as the perilunar dorsal hand luxations. The volar dislocation of the lunate is likely to be accom-

[1] Rev. de Chir., 1913, p. 975.
[2] Beitr. z. klin. Chir., Bd. xciv, S. 148.

panied by fractures of the radial and ulnar styloids, particularly the latter. Oehlecker found in all the 4 cases of perilunar dorsal dislocation that the edge of the os triquetrum was fractured, and that this fracture may lead to bone changes which we have previously described under fracture of the carpal bones. These small fractures and interference with blood supply are probably primary and lead to the conditions described by Preiser as typical, post traumatic osteitis of the lunate bone, which causes spontaneous fracture[1] and the traumatic malacia of the os lunatum of Kienböch.[2] A third and more advanced stage of displacement of the lunate, with or without a fragment of the navicular, consists in its being pushed clear under in an arc of 180 degrees until it lies above the end of the radius under the flexor tendons. The radiolunate ligament may still hold after this extreme rotation, or it may be ruptured. There are only 2 cases of this character with which I am familiar, one reported by Murphy[3] and the other by Taaffe,[4] unless the first case reported by Wallace[5] was of the same character. The lunate and navicular fragments were described as having made two right-angled turns and passed beneath the annular ligament.

In Volume IV of the Murphy *Clinics* Taaffes's case is wrongly ascribed to Buchanan. Taaffe's case was a dislocation of the lunate half an inch above the lower end of the radius in a trapeze performer who fell twenty feet, reduction being accomplished without anesthesia. Mediocarpal and lunate dislocations are not now considered rare, and a large number have been reported in the literature.

Posterior dislocations of the lunate or proximal row of carpal bones are rare—but two or three are reported. Durand[6] reported a case which he had previously recorded in 1907 when the patient had a volar dislocation of the lunate. The bone was removed by operation. The second accident consisted in an injury of the other wrist diagnosed as a sprain which was neglected for eight months. The roentgenogram then proved that there was a dorsal luxation up onto the capitate bone and a fracture of the navicular, a fragment of which accompanied the lunate. These two bones were removed. Goullioud, in 1910, reported a case of dorsal lunate dislocation reduced by manipulation.

I am able to add a case treated this year. There was complete dorsal dislocation of the lunate bone after a fall on the hands from a height. The patient did not know how he struck the ground (see Fig. 364). A distinct lump appeared on the dorsum of the hand at the site of the lunate. Flexion and extension were interfered with to an extent of about 30 per cent. On the dorsum of the hand the extensor tendons stood out very prominently. I made unsuccessful attempts to reduce the bone by pressure and manipulation, but it

[1] Zentralbl. f. Chir., 1910, p. 929.
[2] Ftschr. d. Röntgenstr., Bd xvi, S. 76.
[3] Clinics, June, 1913, p. 431, and June, 1915, p. 401.
[4] British Med. Jour., 1869, p. 398.
[5] Lancet, March 22, 1913, p. 819.
[6] Lyon Méd., 1912, cxviii, 1039.

had been out of place about two months and could not be replaced. The lunate was removed by open operation. The radiolunar and part of the navicular ligaments were intact. There was rotation upward

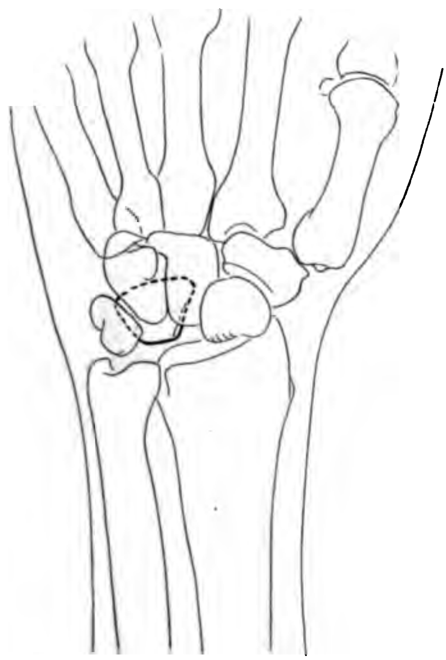


FIG. 362.—Dorsal dislocation of the lunate bone alone.

of the bone about 45 degrees, the concave surface riding over the capitate bone. A small area of avulsion on the dorsoconcave surface seemed to represent the point of pulling out of the dorsal ligament which connected the lunate to the capitate bone (Figs. 362, 363, 364,

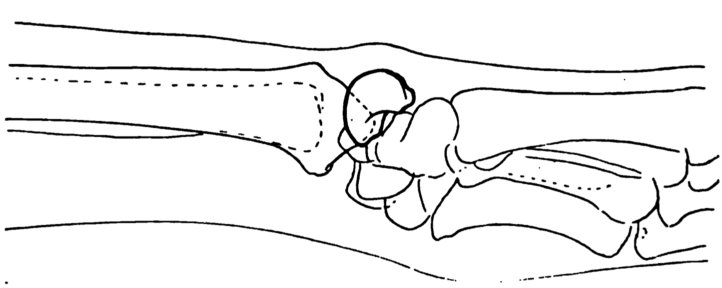


FIG. 363.—Lateral view of dorsal dislocation of the lunate bone.

and 365). They are probably caused by falls on the hand in extreme flexion. A reversal of the hyperextension mechanism occurs, and the distal carpal bones are displaced downward and backward on the

proximal row, the lunate (and navicular) being pushed out on the dorsum of the hand. Wallace in the second case reported in his article,[1] reports that the injured hand was forced back into contact with the dorsum of the forearm, and there remained a prominence on the back of the hand. The roentgenogram proved that this prominence was the capitate, hamate and pyramidalis bones forced upward and backward, that is, a dislocation of the second row of carpal bones on the first, the lunate being displaced backward also. The navicular

FIG. 364.—Photograph of dorsal dislocation of the lunate bone.

remained in position and preserved its usual relations with the greater multangular and lesser multangular bones.[2]

The usual dislocation of the wrist is the one around the lunate bone through the proximal joint, the perilunar dorsal hand dislocation. This occurs about one-fifteenth as often as navicular fracture. The next common variety is dislocation of the lunate accompanied by a part or the whole of the navicular, and rarely the triangular bone and pisiform remain with the two bones of the first row. Other hand dislocations are really those of isolated bones, the volar dislocation of the lunate leading in frequency. Eigenbrodt[3] reported two isolated cases of lunate dislocation. Murphy[4] in four luxations found three of the lunate plus fracture of the navicular through its weakest point and one of the lunate uncomplicated. Although the variation in the type of luxation depends on the force of the trauma, which is probably greater than that producing Colles's fracture, and on the relative position of the hand, the structure and distribution of the individual bones have an influence. The development of the ligaments also has a bearing.

FIG. 365.—Removed dorsally dislocated lunate bone. Note the softening changes.

[1] Lancet, March 22, 1913, p. 819.

[2] DeQuervain, Monatschr. f. Unfallheilkunde, ix, 65; Codman and Chase, Ann. of Surg., xli, 863; Schoch, Beitr. z. klin. Chir., 1907–8, xci, 53; Inaug. Disser. Bern., 1907; Delbet, Bull. et mem. Soc. de Chir., xxxiv, 377; Hirsch, Ergenb. der Chir. u. Orthop., Bd. viii, 753; Lillienfeld, Ztschr. f. orthop. Chir., xx, 437; Destot, Le poignet et les accidents du travail, Paris, 1905; Montandon, Beitr. z. klin. Chir., 1908, Bd. lvii, Heft 1; Ebermayer, Fortschr. a. d. Geb. d. Röntgenstrahlen, 1908, xii, 11.

[3] Bruns, Beitr., 1901, Bd. xxx.

[4] Clinics, iv, No. 3, 389.

Symptoms of Wrist and Lunate Volar Dislocations.—There is always a history of a fall, which the patient may be able to describe completely to illustrate the mechanism of the injury. When direct violence has caused the injury, the description is clearer, and there is no doubt of the direction and nature of the trauma.

If the distal row of carpal bones has been displaced and come to lie posteriorly with the lunate bone rotated downward and pushed out of place, we naturally expect that normal movements of flexion and extension will be lost. Clinically this is so. The amount of motion contributed by the lunate in the 180 degrees between complete flexion and extension is lost. Consequently 90 degrees is gone and only 90 degrees would be left, 45 degrees each for flexion and extension, or one-half normal. Practically, however, the os capitatum in its new bed cannot perform its full function in these motions, and usually a total motion of 50 degrees or less is all that is possible in the wrist. Flexion and extension are therefore greatly limited and are intolerably painful. In the perilunar dorsal hand dislocation there is some swelling and ecchymosis on the dorsum of the hand, and the sharp edge of the os capitatum may be felt. Percussion test of the middle metacarpal is negative, and the displacement of the lunate bone is so little that it cannot be palpated as a separate mass in the wrist. The wrist is shortened, however, when measured from the radial styloid to the head of the middle metacarpal. A lateral view of the wrist gives an appearance of a Colles's fracture with a silver-fork hump, but this hump is located below the end of the radius, which can be palpated above. Radial fracture or fracture of both styloids at the wrist may be a complication, and rupture of the lateral wrist ligament may permit some freedom of motion at that joint but causes greater swelling and pain.

Complete volar dislocation of the lunate is characterized by a shortening of the wrist from the radial styloid to the head of the middle metacarpal. This dropping back of the bone may amount to 1 cm., and be apparent to the eye. Dorsally the proximal edge of the os capitatum can be distinctly palpated, and nearer the wrist is felt the concavity where the lunate has dropped out of place. On the flexor surface there is a distinct palpatory evidence of the displaced lunate beneath the flexor tendons. If the swelling is not great, its outline may be traced. In old cases the bone is distinctly outlined, and if the two wrists are inspected simultaneously the shortening is visible, and the atrophy of the forearm on the affected side is noticeable.

In the rare and complete form of rotation of the lunate up onto the radius the bone can be found beneath the flexor tendons *above* the end of the radius. Crepitus elicited during the examination of the swelling on the flexor side or a secondary tumor mass will lead to diagnosis of accompanying navicular fracture. There is greater restriction of motion and more painful rigidity than in navicular fracture. Practically all cases occur in males, on account of occupation and exposure to trauma. Instances of simultaneous lunate dislocation

in both wrists have been known. Von Frisch[1] from von Eiselsberg's clinic reported a double isolated lunate luxation. The patient fell twenty feet; in the left hand there was a volar luxation and in the right hand a subluxation. Both bones were excised. I have had such a case in a laboring man aged thirty-two years (see Figs. 368 and 370). The lunates were each in volar dislocation, rotated 90 degrees, and the radial and ulnar styloids were fractured in almost identical angles, so similar was the effect of the trauma on both wrists. This case and others bear out the statement that many of these wrist dislocations and fractures are caused by idiosyncrasy of the patient, the mechanism being much like that which causes the ordinary Colles. Before the Roentgen era wrist dislocations were frowned upon, and only specimens which were proved by dissection were accepted as *bona fide.*

Pressure on the median nerve may be present in either recent or old cases. The disturbance may be a numbness or paresthesia in the distribution of the nerve, and the skin may show trophic changes in long-standing cases. The nails become thinned and brittle, and the fingers look shiny and undernourished. The hand lies in partial flexion and is lacking in power. Lateral movements of the wrist are normal, but flexion and extension are limited. The roentgenogram is the final method of determining the injury, and a picture should be made in both anterior and lateral planes, as suggested for carpal fractures, both wrists on the same plate, the tube pointing midway between them and as far forward as the level of the knuckles, according to Codman's method. Stereoscopic pictures of the wrist will give an excellent view of the bones, and when the concavity of the lunate is seen to be separated from the convexity of the os capitatum, luxation is diagnosed. The types with more complete displacement and rotation of the lunate are easily made out by study of the lateral plate. The anterior plate shows the evidence of navicular or os triquetrum fracture and displacement of the fragments as well as injuries of the lower ends of the forearm bones. The navicular is usually broken across the neck or line of the midcarpal joint which divides it into the portions belonging to each carpal row. Only four cases of dislocation of the whole navicular with the lunate without fracture can be found in the literature. They were reported by Nancrede, Hessert, Ely and Finsterer. Fractures of the os triquetrum are usually very small and involve the proximal radial surface on the volar side.

Prognosis.—Some surgeons who have reported these cases believe that the prognosis varies with the treatment and that massage and motion *may* give complete restoration of function. Delbet treated 40 cases by non-operative methods and obtained 27 bad results. On the whole, there are two different types of results: (1) uncomplicated luxations which can be reduced by manipulation give good results; and (2) irreducible or complicated cases treated by operation obtain results depending on whether the bone is reduced after opening or is

[1] Wien. klin. Wchnschr., 1910, No. 4.

excised. The best prognosis follows excision of this latter type. Functional results after manipulative reduction or excision by operation are uniformly good. The cases complicated by styloid fracture usually result in greater restriction of wrist motions. The prognosis may also be partly determined on the basis of the cause. Dislocation caused by indirect violence which leads to fewer complications and is often reducible offers a better prognosis. Direct violence leads to accompanying fracture and also to *tendon* injury, which may delay the final result and cause restricted function. Prompt diagnosis and treatment are more important in these dislocations than in carpal fracture.

Treatment.—Most cases do not come to the surgeon in the condition of fresh dislocation. A sprained wrist is often diagnosed, and the patient attempts to work for days or weeks until the disability compels surgical attention. Navicular fracture cannot be diagnosed with the certainty of lunate dislocation by examination alone, according to the symptoms outlined, and as the function of the hand in fracture is greater than in dislocation and immediate treatment is not so important, the luxations should be studied with vigor that they may be recognized at once. The luxations demand early treatment, as the remote consequences are more serious than those of carpal fractures.

Reduction by manipulation must be first attempted in all cases, regardless of the character of the dislocation. The perilunar dorsal hand dislocations are usually easy to reduce; the volar dislocations of the lunate may not be. Codman and Chase, in their 12 cases, made a comparison of the relative value of methods of treatment and advised immediate reduction of the lunate luxations not complicated by navicular fracture. The method of reduction is as follows:

The patient's hand and wrist are grasped in the operator's hands and the hand is extended with traction to reproduce somewhat the position of the mechanism of the cause. This position pulls the os capitatum away from the radius, and an assistant can then press upon the displaced lunate, while the hand is drawn in extreme extension. As the lunate slips into place the hand is again brought down into flexion while the traction is maintained. The maneuver may need several repetitions before success is attained. In the successful reduction there is a feeling of crepitus and the deformity disappears. Like other dislocations the displacement becomes "old" and is irreducible after a period of fifteen to twenty days, although Codman and Chase reduced 1 case after a month with a perfect result. They reduced only 2 of their 12 cases by manipulation, the other 10 being operated on. Other uncomplicated instances of lunate dislocation have been successfully reduced through manipulation by Douglas,[1] Vulliet,[2] a case reported by Bazy, who reduced one a week after the luxation,[3] and Runyan,[4] who so reduced 3 out of 7 cases. One of these 7 was

[1] Ann. of Surg., lxi, 472.
[2] Revue Med. de la Suisse Romande, Geneva, February, 1915, xxxv, No. 2, p. 58.
[3] Bull. et. mem. Soc. de Chir. de Paris, 1914, xl, 965.
[4] Surg., Gynec. and Obst., 1915, p. 60.

a solitary displacement of the lunate, and 2 were complicated by navicular fracture. After failure of reduction by manipulation open operation is the procedure. Skillern[1] made a manual reduction of the dislocated lunate, which was complicated by fracture of the navicular and triangular bones. The result was good after four weeks' immobilization without massage. Operative treatment may consist of open reduction of the displaced bone or complete excision. Most of the German authors advise excision (Hirsch, Oehlecker, etc.), even before manipulation is tried. Excision is undoubtedly the choice in complete volar dislocation of the lunate accompanied by fracture of the navicular and fragment dislocation. No case of this character has ever been reduced by manipulation, and instances in which the lunate has been returned to place have not turned out well. If there is interference with the median nerve, or the case is of long standing with pain and stiffness, excision is the choice. Rarely in fresh fracture-luxation a replacement is made which terminates happily. Runyan's case 2, which had a fracture of the navicular and was reduced by manipulation, did not turn out well. Likewise his case 3 with a similar lesion, in which the lunate was reduced by open operation, did not result well. He thinks closed reduction can be accomplished in about half the cases, and if this method fails, open reduction should be attempted, excision being kept for the last step. Murphy[2] is also of this opinion. Vulliet with 2 cases, 1 of excision, obtained best results from the operative removal, and the 2 cases of excision cited by Oehlecker gave almost perfect result, both seen after four or five years. He advises removal of the bone to avoid the nutritional changes which so often follow accompanied by grave functional loss. Pool[3] obtained a fair result following excision, as the wrist motions after a year were full and strong except those of extreme adduction. This result was influenced by the change of posture of the carpal bones whereby the triangular was closer to the tip of the ulnar styloid, against which it impinged in extreme adduction. In Wallace's 3 cases he excised the lunate and the fractured displaced portion of the navicular when present, with good results but rather slow recoveries. Jaboulay[4] reported a case of fractured and dislocated navicular and radial styloid with lunate dislocation. The fragments were all removed about a month after the accident, but a median paralysis which was supposedly caused by pressure of the navicular fragments had not improved much within six weeks afterward. Hitzrot[5] obtained an excellent final result after excision of the luxated lunate in a case complicated by navicular and radial styloid fracture. When the luxation is of two weeks' standing or longer, the efforts at reduction are necessarily violent, and they may traumatize the joint and lead to permanent arthritic changes. Bérard[6] recorded one case reduced twenty-three days after luxation which had a slow functional return

[1] Ann. of Surg., lviii, 716.
[2] Clinics, iv, 411.
[3] Ann. of Surg., lv, 626.
[4] Lyon Med., 1913, cxxi, 699.
[5] Ann. of Surg., lii, 261.
[6] Lyon Chir., 1914, xi, 101.

and a swelling lasting for months. His second case was a double dislocation of seven months' standing which had resulted in 45 per cent. functional use of the hands. In the right wrist the lunate was dislocated forward with a fracture of the navicular, while the left wrist was an isolated forward lunate luxation. Both lunates were excised with an excellent functional result and loss of symptoms of median nerve involvement.

The after-treatment of all cases, whether reduced by manipulation or open operation and by excision, consists in wrist immobilization on a moulded or padded splint from the middle of the fingers to the elbow for from three to four weeks. Use and motion are permitted after that, and massage is given to return tone to the forearm muscles.

The Technic of Operation.—A one-and-a-half inch longitudinal incision on the volar side of the palm is made, slightly to the radial side of the middle line. The distal end of this incision does not project far enough to endanger the palmar arch. The deep fascia is divided, and the flexor tendons are retracted without injury to their sheaths. The lunate is discovered and an attempt made to replace it. In old dislocation or in case of irreducibility the bone is excised, together with the fragment of the navicular, by sharp dissection of remaining ligamentous attachments to the radius and ulna. Ligatures are rarely needed, and a deep running catgut stitch is placed in the fascia after the tendons have been allowed to fall back into place. The skin is closed, and a splint is applied. Inside of a few hours the patient can flex and extend the hand painlessly and to a greater degree than before operation.

ISOLATED DISLOCATION OF CARPAL BONES.

From the remarks on mediocarpal dislocation and fracture dislocation of the lunate and navicular bones, one readily understands that luxation of isolated carpal bones excluding the lunate, must be rare. The close division into two rows of carpals, their intimate anatomical and functional connection, and the strong interosseous ligament bands preclude frequent solitary dislocations. A large share of the isolated dislocations are partial in character, one end of the bone slipping out of place. The complexity of the ligaments and the crowded condition of assigned space in the wrist favors a recurrence, and these dislocations frequently become habitual, because replacement is often incomplete, the infolding of torn ligament surfaces blocking reduction. Roentgenograms in two planes with stereoscopic pictures are needed for absolute diagnosis (Fig. 366). Figs. 367, 368, 369, 370, and 371

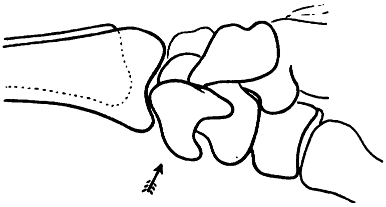


Fig. 366.—A case of ordinary volar dislocation of the lunate alone.

illustrate the author's case of simultaneous volar dislocation of the lunate bone in both wrists.

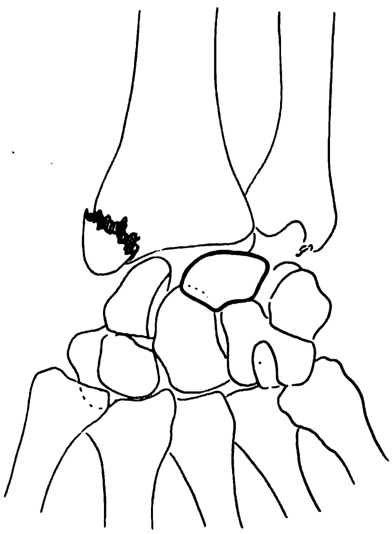


FIG. 367.—Simultaneous dislocation of the lunate bones of both wrists. Note that the radial and ulnar styloids are fractured.

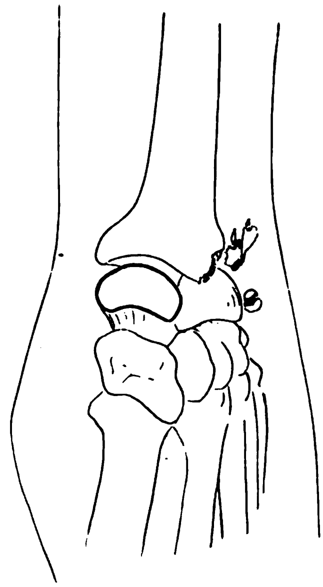


FIG. 368.—Lateral view of same wrist as the preceding figure. Note the radial fragments.

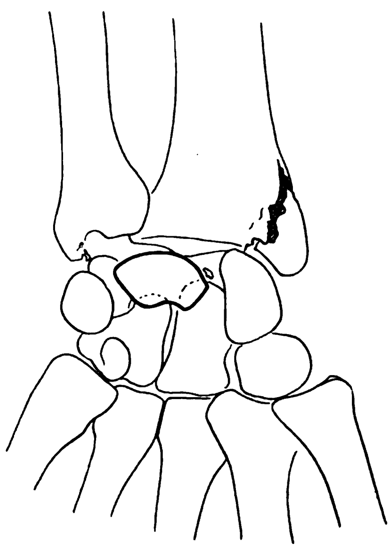


FIG. 369.—The opposite wrist with similar fracture and volar dislocation of the lunate.

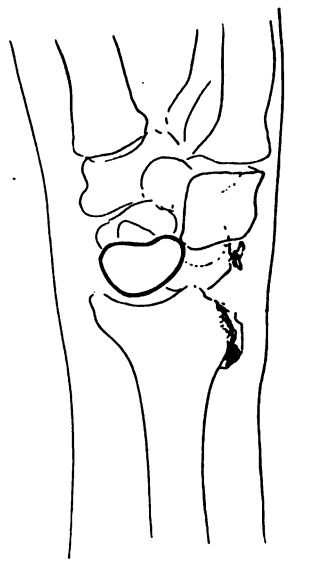


FIG. 370.—Lateral view of the second wrist. Note that the dislocated lunate does not seem to cause swelling on the palmar surface of the wrist.

The Navicular Bone.—This is frequently dislocated with the lunate, usually only a portion of it is displaced, however, as the combination of navicular fracture and lunate dislocation is the usual one resulting from trauma exerted across the mediocarpal joint. The position of the navicular between the two rows of carpal bones makes it a bone of contention in wrist injuries. Falls with the hand in radial flexion cause its fracture; if hyperextention is present, fracture and dislocation of the proximal fragment with the lunate is the injury to be expected. If the hand is in ulnar flexion, as we have seen, the lunate becomes the centre of action, but may drag part of the fractured navicular into displacement.

Luxations of the navicular bone without fracture and alone, are very rare. Eigenbrodt's collection contained a few cases. King, in 1899,[1] reported a case on which he operated for reduction. The patient was a twenty-one-year-old student who fell on hands and knees in the gymnasium. A small bunch seen on the anterior surface of the right wrist was soon lost in the general swelling. An anterior

FIG. 371.—The two lunate bones of the simultaneous double dislocation removed by operation.

dislocation of the navicular alone was recognized after four weeks' treatment, the bone making a marked protrusion in front of the wrist with a deep depression behind. No flexion in the wrist was possible on account of position of the navicular in front of the radius. When the bone was cut down upon, its radial surface was found directed forward, having completely rotated. The adhesions were broken up and the bone was slipped back into place by extension, pressure, and flexion, a subsequent roentgenogram verifying its correct position.

Practically all the isolated navicular dislocations have been backward, and some have been partial. The radial styloid may be broken, and the extensor tendon at the base of the thumb is pressed against, so that unreduced cases may lead to an adhesive tenosynovitis in this tendon, with restriction of thumb movement. Recent navicular dislocations can nearly always be reduced by pressure; if backward, by pressure and flexion; if forward, by pressure and extension. Old dislocations or partial dislocations with nerve and tendon symptoms

[1] Ann. of Surg., 1899, xxx, 213.

must be treated by open operation. The bone may be levelled off by a chisel after exposure or be completely removed.

Os Lunatum.—The luxation of this bone has been discussed in the previous paragraphs on mediocarpal dislocation. The older literature on the subject is unreliable, and the recent cases verified by roentgenograms bear out the ideas of Codman, Chase, and Delbet that the luxation of the lunate and fracture dislocation of the lunate and navicular fragment constitute the greater part of wrist dislocations. The varying degrees of lunate dislocation, from the perilunar dorsal dislocation of the hand to positions of partial rotation of the lunate on the anterior radio-ulnar ligament as an axis, to complete volar dislocation of 90 degrees and the third stage of 180 degrees rotation up on to the radius, are probably all caused by the same mechanism. The continuation of the force and its original intensity govern the relative displacement.

Os Capitatum.—Dislocations of this bone are always backward and many are pathological.[1] The older cases in the literature were not confirmed by operation, and the first authentic case of total dislocation is the one seen by Stimson in 1899.[2] That case was of nine years' standing and caused no loss of function. The roentgenogram shows a displaced os capitatum with several areas of cystic degeneration, the other carpal bones appearing normal in contour and position. Demoulin[3] has reported 2 cases of dorsal luxation of the os capitatum with enucleation of the lunate. They were both reduced under general anesthesia, and satisfactory results followed. The first case was Monchet's, and was a thirty-seven-year-old man who had suffered a back-fire injury while cranking an automobile. The anteroposterior diameter of the wrist was increased, and the soft parts were so edematous that the wrist was globular in shape and was locked in position. The roentgenogram showed a total volar dislocation of the lunate and a backward dislocation of the os capitatum. The second case (Mathieu) was characterized as a subtotal retrolunar dislocation of the left wrist with fracture of the styloid and a rotation of 90 degrees of the displaced lunate. Cotton reports a case in a muscular man who suffered backward displacement of the proximal end. It was reduced.

Treatment.—Treatment of these dislocations is similar to that of the other wrist luxations. Bloodless reduction must first be tried, because when it is successful the resulting function seems satisfactory. Under general anesthesia the hand is placed in hyperextension (if the lunate is displaced), traction is made on the metacarpals through the fingers, and the concave surface of the lunate is hooked over the head of the os capitatum. Complete reduction is made by the pressing of the os capitatum down into position. Delbet considers that the hyperextension also draws out the anterior wrist ligament which has slid between the os capitatum and lunate.

[1] Sulzberger, Fortschritte a. d. Gebiete der Röntgenstrahlen, 1901–2, p. 172.
[2] Fractures and Dislocations, 7th edition, p. 770.
[3] Bull. et mem. Soc. de Chir. de Paris, 1914, N. S., xl, 965.

Hamate Dislocations.—There are very few of these known. I find six, as follows: Buchanan,[1] Oberst,[2] Ebermayer,[3] Eigenbrodt,[4] Van Assen[5] and Murphy.[6] Murphy's case offers the latest and clearest description. The patient, a twenty-two-year-old male, caught his left hand between two rollers and suffered much pain with swelling of the wrist and forearm. Splints and massage failed to give much relief, carpal fracture had been diagnosed, and after three months he had a restricted range of wrist motion, particularly flexion and pain on use. The examination showed a dorsal bony prominence located near the ulnar side of the hand, distinguishing it from the palmar deformities near the radial side of the common anterior dislocations of the lunate and navicular bones. This projection was also in line with the distal row of carpal bones, and there was a distinct shortening of the carpus on the ulnar side of the hand, shown by the relative proximal retraction of the knuckles of the little finger when the closed fists were compared. The extensor tendons of the fourth and fifth fingers were raised by the displaced bone. The anteroposterior roentgenogram showed that the hamate bone lay approximately in normal position but that its shadow overlapped slightly the adjacent two metacarpals and the os capitatum. A lateral view demonstrated the hamate lying dorsal to the second carpal row, and there was no fracture. The bone was excised through a dorsal incision to relieve the paresthesias on the back of the last three fingers, probably caused by pressure on the ulnar nerve. Van Assen's case was complicated by dislocation of the navicular lunate. Ebermayer's case was an open luxation which was left to heal. After seven months the patient refused operation and there was atrophy of the thenar muscles and loss of function.

Pisiform.—A few cases of dislocation of this bone are known. They are caused by direct violence or muscular action, and if the tendon below, abductor of the little finger, and the ligaments are torn the bone may be drawn upward on the wrist by the flexor carpi ulnaris muscle.

Cotton[7] records a case occurring in a scrub girl aged twenty years, who slipped and struck her hand against the floor. There was tenderness and a click to be elicited in the freely movable pisiform. A diagnosis of partial luxation was made, but immobilization gave no relief.[8]

Greater and Lesser Multangular Bones.—A few cases of backward dislocation of the lesser multangular bone have been reported. There is a raised deformity on the dorsum of the wrist at the base of the index metacarpal. Sheldon[9] reported a case which could not be

[1] Philadelphia Med. and Surg. Reporter, 1881–82, xlvi, 418.
[2] Fortschr. a. d. Geb. d. Röntgenstrahlen, 1901, 1 Heft, 15.
[3] Ibid., 1908, xii, Case XVIII.
[4] Bruns, Beitr., xxx.
[5] Zentralbl. f. Chir., 1910, p. 1129.
[6] Clinics, iv, 423.
[7] Dislocation and Joint Fractures, p. 373.
[8] Eigenbrodt, Beitr. z. klin. Chir., 1901, xxx, 805; Barois, Arch. de Med. Mil., 1891, Bd. xviii, 55.
[9] Am. Med. Jour. Med. Sci., January, 1901, N. S. 121, p. 85.

reduced but which gave a good functional result after several weeks. Sheldon's case is the second on record and occurred at the Cook County Hospital. It was almost exactly like Gay's,[1] whose patient struck a post in such a manner that force was borne against the metacarpal of the thumb and index finger, the wrist being straight. There was a quadrilateral swelling proximal to the metacarpal of the index and a bony projection of a quarter of an inch beyond the dorsal surface of the carpal bones. Reduction by pressure was not possible. Sheldon's patient, a policeman, struck a man with his fist. The right wrist was slightly flexed, and there was a similar swelling proximal to the base of the index metacarpal which was not very painful. Partial reduction was accomplished by extension of the index and pressure over the bone, but the deformity, projecting one-fourth inch, remained. This was strapped, but fifteen weeks later the deformity was still present. Sheldon experimented on a dozen cadavers to reproduce this luxation but did not succeed in doing more than fracturing the index finger until he freed the ligamentous attachment of the lesser multangular bone from the other carpal bones. He then obtained a simple dorsal dislocation of the bone by applying force on the distal end of the second metacarpal, and he concluded that the two cases known were probably caused by congenital weakness or absence of ligaments, with possible maldevelopment of the carpal bones. Only a few cases of dislocation of the greater multangular are on record.[2] The deformity lies just above the anatomical snuff box and the dislocations are partial in character. They might interfere with thumb motions or induce tendon changes and adherence. Sulzberger[3] reported a case. Cotton reported a case which was a complication of mediocarpal dislocation and was not reduced.

CARPOMETACARPAL DISLOCATIONS.

Luxations at the carpometacarpal joint are caused by indirect violence from falls or directly from blows of objects. Isolated dislocation of every metacarpal bone except that of the little finger, and also combinations of one or more, have been reported. The most important is the thumb metacarpal, which furnishes the greatest number of instances. Luxation of the thumb metacarpal may be backward, the most common; forward or outward, the two latter very rarely. The cause is usually a fall or blow which drives the thumb inward to the palm, the muscle mass of the thenar group acts as a fulcrum and the lower end of the metacarpal is levered outward and backward. Backward dislocation is complete or incomplete. In the complete form the thumb is flexed toward the palm of the hand, and the posterior edge of the proximal end of the metacarpal can be felt slightly displaced

[1] Boston Med. and Surg. Jour., 1869, p. 188.
[2] Mosengiel, Langenbeck's Arch., Bd. xii, 723; Bonnes, Giorno Veneto, Settembre, 1865.
[3] Fortchr. a. d. Geb. d. Röntgenstrahlen, 1901–2, p. 172.

backward at the joint, with the tense tendons passing over it. There is pain, swelling, and limited motion, and the displacement may be reduced by pressure over the deformity. Complete dislocation produces the same symptoms with a greater deformity, the metacarpal riding back on the lesser multangular bone, and the thumb appears shortened. Reduction is not difficult, but its maintenance is.

Recurrent cases lead to great thickening about the joint and a permanent condition of subluxation. Reduction is made by traction outward on the thumb, with direct pressure over the displaced end of the bone. A permanent dressing can be made of adhesive plaster to hold the thumb in abduction and extension, or a small plaster cast embracing the thumb can be applied for two weeks. Carrette, in 1894,[1] collected 24 cases, Chancel in the same year,[2] 30 cases, and Arnal, in 1905, added 5 more. Potherat, in 1912,[3] recorded 1 case and Soubeyran[4] added 3 more, including Regnault's[5] and also Arron's case.[6] The second case of Soubeyran's was reduced after being luxated three years, but it became redislocated a week after the cast was removed.

A few cases of dislocation of the second metacarpal have been reported, perhaps ten in all. Most of these have been backward. Lyman[7] states that Buck has collected 24 cases of dislocations of two or more metacarpal bones on the carpus, including all five bones and forms of complete and incomplete luxation. Boyer reported 16 cases, 11 incomplete and 5 complete. Hamilton's case of the second metacarpal occurred in a twenty-eight-year-old woman from a fall, and Humbert's case followed a kick by a horse. Lyman's case was in a young man who fell off a street car. His hand showed no evidence of trauma, but there was a prominence in the hand outline on the dorsum at the proximal end of the second metacarpal. The dislocation was easily diagnosed, but traction with pressure failed to reduce the deformity. An open operation showed the metacarpal completely overlapping the trapezoid, and a chisel placed between the two bone ends effectively pried them into place with a snap. There was no tendency to recurrence.

There are a few other reports of isolated dislocations of the third and fourth metacarpals which have nothing distinctive in their description. The four finger metacarpals have been dislocated at once. Stimson records a case in a fifteen-year-old boy who fell down an elevator shaft. The hand was extended on the wrist and lay anteriorly to the plane of the forearm. There was a well-defined ridge on the back of the hand at the metacarpal border, and the ball of the hand was thickened. Reduction was made by pressure and traction but the dislocation recurred at once. A final healing in a satisfactory position with mobility of the fingers was obtained by the placing of the hand in a plaster dressing for three weeks.

[1] Thèse de Paris.
[2] Ibid.
[3] Soc. de Chir., March 13, 1912.
[4] Rev. d'Orthop., 1912, 3 S. iii, 385.
[5] Soc. de Chir., 1912, p. 416.
[6] Soc. de Chir., 1912, p. 419.
[7] Ann. of Surg., xliii, 906.

All five metacarpals have been dislocated. Poulet[1] reported a case and referred to Ericksen's[2] and Rivington's,[3] whose case was a lacerating open injury which necessitated immediate removal of bone fragments. Poulet's patient was thrown from a horse. There was an open wound with great swelling, and after fifteen days' antiseptic treatment a bony prominence at the line of the distal edge of the capitate bone was noticed. On the volar side of the hand the palmar crease had disappeared, and the carpal bones seemed all displaced backward, with a thickening of the anteroposterior diameter of the wrist. A partial reduction was accomplished, and after the swelling had subsided a fair function resulted.

METACARPOPHALANGEAL DISLOCATIONS OF THE THUMB AND FINGERS.

These dislocations are the common ones of the fingers, and the thumb presents many difficulties of reduction. A complete discussion of thumb dislocations was made by Farabeuf,[4] to which the reader is referred for details. The head of the thumb metacarpal is enlarged on the palmar surface, and the articulating area is covered by smooth cartilage. The head projects slightly on the inner side and is held in place by the lateral and anterior ligaments. The anterior ligament is very strong and in the adult is supported by two small sesamoid bones (Fig. 372). Farabeuf was unable to tear off the thumb by traction, as surgeons had reported doing in attempts at reduction of dislocation, although he used a force of 150 kilograms and cut away the skin over the joint.

The various muscles inserted in the thumb have an influence on the displacement of dislocation, particularly the flexor pollicis longus which lies on the inner side and is connected with the capsule of the metacarpophalangeal joint (see Fig. 373). The muscles in the thenar group are tightened when the thumb is abducted, and to produce a maximum relaxation of flexor pollicis brevis, abductor pollicis brevis, and adductor pollicis transversus, the thumb must be adducted into the palm with the hand held straight out on the wrist and in slight abduction.

Types of thumb dislocations at the metacarpophalangeal joint are as follows:

(1) Posterior dislocation, the usual form which is complete or incomplete.

(2) Anterior dislocation.

(3) Lateral dislocation, which may complicate the first two.

Posterior Dislocation.—Posterior dislocation is caused by hyperextension of the thumb from blows on the distal phalanx, as in striking

[1] Bull. et Mem. de la Soc. de Chir. de Paris, x, 902.
[2] Science and Art of Surg., London, 1864, 4th edition, p. 313.
[3] Lancet, i, 270.
[4] Bull. et Mem. de la Soc. de Chir. de Paris, 1876, ii, 21.

against a baseball. The phalanx is luxated backward on the metacarpal, and the anterior ligament is ruptured across, accompanying the phalanx in the displacement.

Complete Form.—The thumb phalanges assume either of two positions (Fig. 374). In the first position they stand erect, the articular surface of the phalanx rides on the dorsum of the metacarpal, and the rounded head of the metacarpal lies forward, thrust through the rent in the capsule. The lateral ligaments are also torn, and the attached

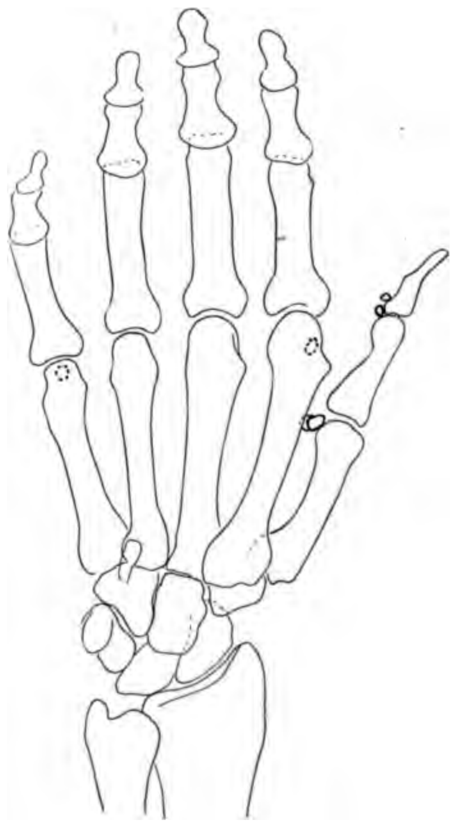


Fig. 372.—Roentgenogram of hand, showing the usual sesamoids to be found. Note particularly those of the thumb.

muscles hold the distal portion of the thumb in the erect position, the flexor longus pollicis being stretched over the head of the metacarpal or lying at one side. The sesamoids may separate, one going to either side of the metacarpal head, or in the complex form described by Farabeuf they may adhere closely to the torn capsule and be carried up between the metacarpal and phalanx. He believed that the sesamoids caused much of the difficulty in reduction (Figs. 375 and 376).

In the second position, the distal portion of the thumb, instead of remaining erect, held by the short muscles, has been manipulated or pushed by the force until it has been placed further backward and

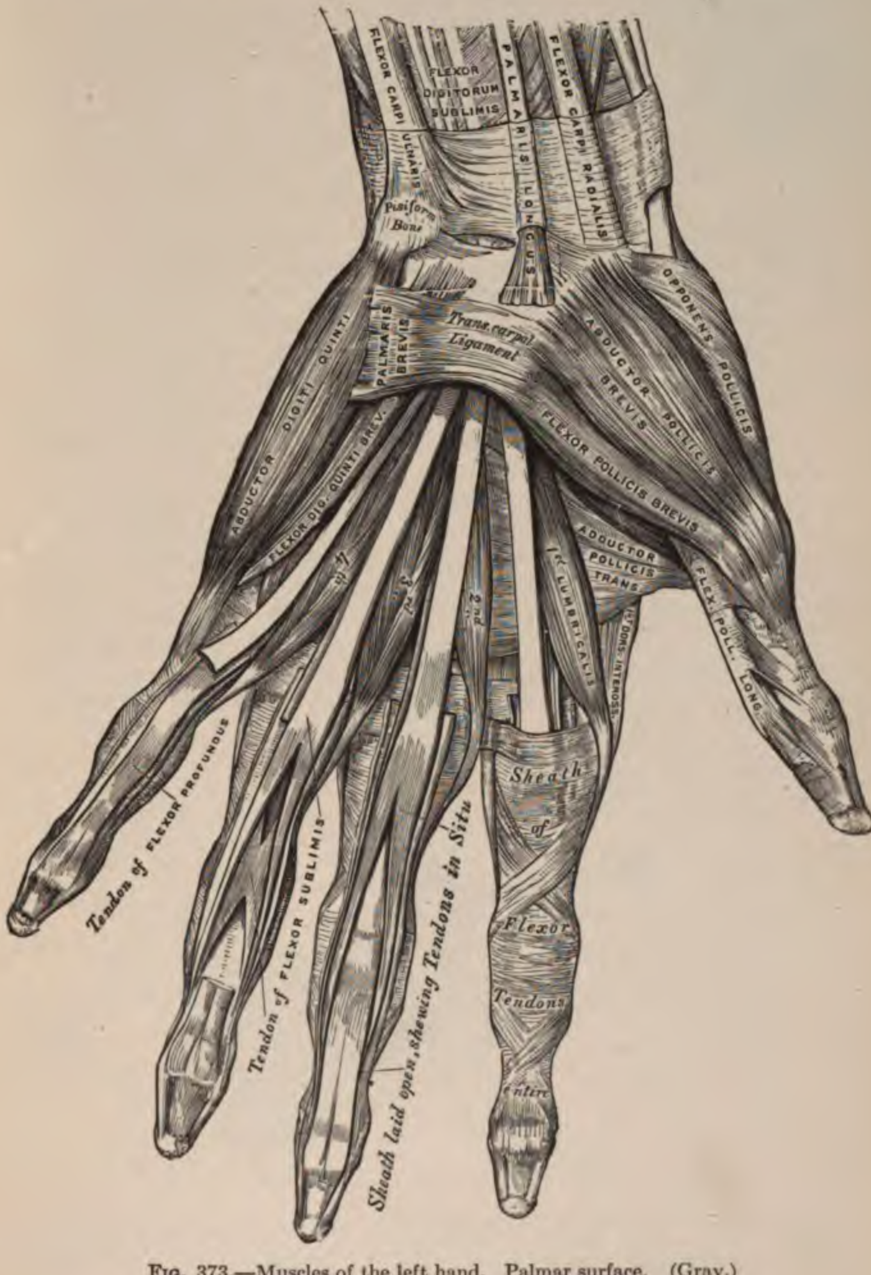


Fig. 373.—Muscles of the left hand. Palmar surface. (Gray.)

brought down into a line parallel with the metacarpal without reductions being accomplished (Fig. 377). The capsule (and occasionally the sesamoids) lies between the bone ends and causes obstruction to reduction, the muscles exerting less influence.

Fig. 374. — Complete posterior dislocation of the thumb; phalanges erect.

Incomplete Form.—The capsular tear and the trauma are not so great, and the phalanx has not been luxated completely away from the metacarpal head. It lies in part contact against its posterior surface, held by the remaining intact portion of the capsule and the stretched muscles (Figs. 378 and 379). The incomplete form may become an habitual subluxation from repeated traumatism, and some persons can luxate and replace the joint at will by muscular action. The thumb does not stand so erect as in the complete form, and the head of the metacarpal is not so prominently palpable, nor is the distal portion of the thumb as mobile laterally as in complete dislocation.

Treatment.—Nearly all fresh posterior dislocations are reducible by manipulation. The short muscles of the thenar group must be relaxed before the luxation can be reduced, and, as we have previously seen, this is accomplished by a position of the hand in a straight line with the forearm, with slight abduction and adduction of the thumb toward the palm. The metacarpal is also pressed in toward the palm to aid in the muscular relaxation. The manipulation proceeds by hyperextension of the thumb. As the muscles relax, the phalanx

Fig. 375.—Simple complete dislocation; outer side. (Farabeuf.)

in a hyperextended position is worked down over the head of the metacarpal by being pushed and rocked until it is felt to slide over

Fig. 376.—Simple complete dislocation. (Farabeuf.)

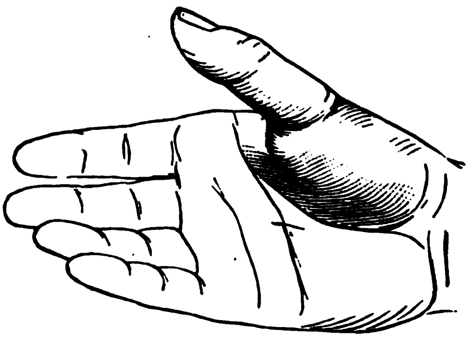


Fig. 377.—Complex dislocation. (Farabeuf.)

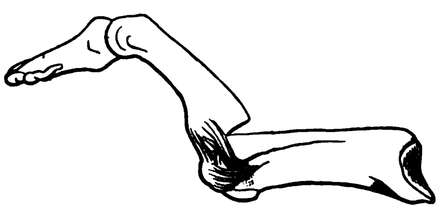


Fig. 378.—Incomplete dislocation of the thumb. (Stimson.)

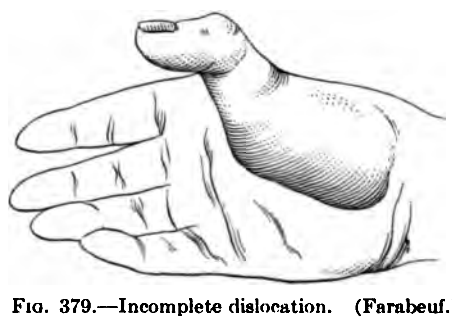


Fig. 379.—Incomplete dislocation. (Farabeuf.)

into normal position, after which the distal portion of the thumb is flexed and the replacement is finished. There is little tendency to recurrence. The thumb is dressed in a position of slight flexion by either a plaster splint or a small cast, or most often by being strapped with adhesive plaster close into the palm. Ten days in this position permits a healing of the torn ligaments, and use is then begun.

Capsular interposition with aid of the sesamoids may prevent reduction, and arthrotomy is then indicated. A longitudinal incision over the lateral palmar surface of the prominent metacarpal head is made. If the head extends out through a buttonhole in the capsule, this is enlarged, and reduction is made under sight by the manipulation suggested previously. Obstruction by the interposition of capsule and sesamoids requires a larger exposure; the thumb is hyperextended and the obstruction is overcome by drawing with a force on the distal end until the reduction can be accomplished.

A stiffened or enlarged joint may result from any kind of reduction. A prolonged immobilization after reduction favors a better functionating joint. With arthrotomy there are now no failures of reduction. Many of the cases formerly reported unreduced obtained some function even in the presence of deformity and limited motion.

Anterior Dislocations.—Anterior dislocations are very rare. They are caused by falls or blows which drive the thumb inward while in a position of hyperextension or hyperflexion. The phalanx is displaced in front of the end of the metacarpal, which rides on the dorsum of the phalanx. The capsule is usually torn on the posterior and lateral aspects, and the flexor tendons are stretched over the metacarpal head or are displaced laterally. There has usually been noted some rotation with this anterior dislocation.

Treatment.—Treatment is not difficult; reduction usually follows traction on the thumb, accompanied by flexion and compression on the phalanx backward. Arthrotomy is performed for recurring cases to strengthen the capsule, or for irreducible luxation.

Lateral Dislocations.—Lateral dislocations have been reported, and some lateral displacement often accompanies the two other forms. Lateral luxation can be replaced by traction and direct pressure.

METACARPOPHALANGEAL DISLOCATIONS OF THE FINGERS.

Phalangeal Dislocations of All Five Fingers.—The metacarpophalangeal joints of the fingers are similar in anatomical structure to the thumb-joint, and the anterior capsular ligament is the strongest. The index and little fingers are often supported at this joint by sesamoids (see Fig. 372).

Posterior dislocations predominate over all other types, and the total dislocations of all fingers do not equal the number involving the thumb alone. Hyperflexion from direct or indirect violence bends the finger back until the anterior capsule is torn across near the metacarpal insertion, permitting the finger to be displaced backward, as

in thumb luxations. The luxation may be complete or incomplete, more often the former, and is frequently complicated by fracture of the metacarpal near the hand. Interposition of capsule and sesamoid bones has been noted in these dislocations also, and the main obstacle to reduction is the infolding of the capsule over the end of the phalanx.

Shortening and rigidity of the affected finger in a position of flexion are noticeable. The phalanx is pushed back so that the knuckle is deformed by a hump on the back of the hand, and the head of the metacarpal can be felt in the palm. A partially erect position of the finger is possible when the displacement is great, and the attached tendons hold the finger firmly against the metacarpal, all the joint ligaments being torn. Amandrut[1] recorded a case of complete backward dislocation of the metacarpophalangeal joint of the left middle finger in a boy aged eleven and a half years. There was also a fracture of the ulna just above its lower end and a separation of the radial styloid. Reduction attempted by hyperextension and traction on the finger failed. A pointed tenotome was then inserted on the dorsal aspect of the hand near the head of the metacarpal and at the outer side of the extensor tendon of the finger. All the interposing soft parts down to the articular surface were divided and the finger was guided into position by traction and manipulation.

Treatment.—Reduction of incomplete luxation is not difficult. The patient will often reduce by making traction himself on the distal end of the finger to pull the joint into place. Cases coming to the surgeon are treated by traction and flexion, when the phalanx slips over the metacarpal. Complete luxation is often difficult to reduce. The method used for thumb dislocations should be used, namely, the finger should be forced into hyperextension and then the phalanx should be pushed down over the metacarpal, being rocked to force the torn capsule out of the way. Old cases and irreducible ones, especially those complicated by fracture of the metacarpal, will need arthrotomy for reduction. An incision over the palmar aspect of the metacarpal head reveals the joint after the tendons are retracted, and the bone can be pried into position, the interposing capsule being lifted out of the way. Complicating fracture increases the difficulty of reduction, and I have never been able to reduce complete posterior luxation in the presence of fracture without an open operation.

Peraire[2] reported a bloody reduction of a backward dislocation of the little finger. He found that the sesamoid on the flexor tendon obstructed reduction, and after cutting the glenoid ligament, he was able to pry the two bones into position. Ozenne, discussing the report, inquired why Farabeuf's method of hyperextension and shoving reduction had not been tried.

Forward dislocations of the metacarpophalangeal joint are infrequent. The deformity is reversed: a projection exists forward in the palm of the proximal end of the phalanx, and a prominence of the

[1] Rev. d'Orthop., 1912, 3 S., iii, 95.

[2] Paris Chir., 1911, iii, 817.

metacarpal head on the dorsum. The fingers may be slightly extended, with flexion of the two distal phalanges. Reduction is made by traction, pressure against the base of the phalanx, and flexion.

Dislocations at the Second Phalangeal Joint.—These luxations may be backward, forward and lateral in combinations. Backward luxation is the most common and is caused by direct or indirect violence. Capsular tear and the pull of the muscles determine the position of the distal bone, which may be partially erect or may lie prominently displaced backward in the same longitudinal axis as the second phalanx. Delaunay[1] reported a posterior external luxation of the ring finger in a woman aged thirty-six years, caused by its being caught in a wire of a machine. The second phalanx made an obtuse angle of 110 to 120 degrees with the first phalanx and was deviated inward so that the terminal phalanx lay across the palmar surface of the middle finger.

Reduction is made by traction and direct pressure on the phalanx. If the flexor tendon interferes with replacement, the distal phalanx may be rotated and shoved into place.

Forward luxation of the middle phalanx is characterized by displacement of the base of the phalanx upward on the palmar surface of the proximal phalanx, which assumes a correspondingly prominent position on the dorsum of the finger. There may be some lateral deviation, as in a case of Delaunay's.[2] A forty-eight-year-old man fell from a carriage and caused an antero-external dislocation of the second phalanx of the index finger. There was no fracture, and reduction was made by traction in the long axis. The combination of anterior and lateral luxation was probably caused by a rupture of the flexor tendon after the anterior luxation occurred. Reduction is generally simple by direct traction and pressure.

Lateral dislocations are rare. There are not more than nine or ten cases on record, and Delaunay disputes Rollet's case of external luxation at the second phalanx. Many of the lateral displacements are partial, and there are open wounds, the position of the bones being determined by the extensive laceration of the soft parts. There is some shortening, an angular deformity, and a position of flexion of the distal portion of the finger. Replacement is obtained by traction and pressure.

Luxation of the distal phalanges are similar to those of the second phalanx and may be backward, forward, or lateral. The backward dislocations are the usual type (see Fig. 380), anterior dislocations having been found in the thumb alone. They are caused by direct blows or falls on the fingers. As in the other finger joints, the anterior ligament which is the strongest, is subjected to a breaking strain and the distal phalanx slides back over the second, assuming any position between hyperextension and flexion. The injury may cause an open wound.

[1] Paris Chir., 1912, iv, 18.

[2] Ibid., 1911, iii, 842.

Reduction is not easily accomplished, because there is so little of the distal phalanx to grasp in making traction, and the pull of the flexor tendon is hard to overcome. About one-quarter of the reported cases have failed to yield to manipulative methods of reduction. Arthrotomy is indicated if the bone cannot be shoved back after traction fails. The proximal portion of the thumb or finger is grasped in the operator's two hands and the luxated bone is pushed into place with his thumbs. By open operation the lateral ligaments can be

Fig. 380.—Backward dislocation of distal phalanx.

severed and the capsule or flexor tendon can be pulled out of the way. Bilhaut[1] reported a case of backward dislocation of the distal phalanx of the thumb which resisted manipulative efforts even after the injection of cocain about the joint. The patient was given chloroform, and through a lateral external incision over the joint the lateral ligament was cut and a reduction obtained. The capsule was sutured and a primary union resulted.

[1] Ann. de Chir. et d'Orthop., Paris, 1911, xxiv, 321.

also possible for the catheter to pass through the bladder rent and enter the free abdominal cavity. Little or no urine is obtained; abdominal symptoms of pain, distention, and increasing flank dulness are evident.

The rectum or sigmoid may be ruptured. An extravasation of fecal material into the perirectal tissues and perineum, or into the abdomen, results with inflammatory symptoms, and there is a bloody stool or evidence of blood found in the rectum by the tube. Nerve injury of the sacral plexus is rare, unless there is severe crushing injury of the sacrum. Traumatic hemorrhages, rupture, and ileus in the bowel are complications to be feared after severe crushes. Lounsbury[1] reports an interesting case which died on the ninth day.

Separation of the symphysis pubis occurs in child labor and also in traumatic cases. In the latter class the separation may be very

Fig. 387.—Wide separation of the symphysis pubis accompanied by fracture of the pubic rami.

great or simply a slight starting. Falls and severe strains, as horseback riding and forcible separations of the thighs, are the cause (see Fig. 387). They may be accompanied by fracture or separation of the sacro-iliac joints, but visceral complications are less frequent than in fracture of the rami. A palpable gap is present except in cases of little separation, and there is local pain and tenderness on pressure. Walking, and pressure on the pelvic brims, are also painful. The separation may be between cartilage and bone or right through the cartilage, giving a ragged faint shadow in the roentgenogram. The prognosis depends on the visceral and bone complications, many cases leading to fatal termination. Other combinations of fracture and dislocation involve the pubic rami and symphysis, the sacro-iliac

[1] Railway Surg. Jour., 1914, p. 9.

femoral heads and down the legs. This is strengthened by a secondary arch composed of the rami and bodies of the pubic bones which resists spreading. The second main arch is the ischiosacral, which transmits the body weight to the tuberosities of the ischium. This is also supported by a secondary arch, formed by the rami of the ischii and pubic bones. There are in addition, lateral and anteroposterior arches to resist strains in those directions. The pelvic ligaments are also very strong and so situated and crossed that they increase the resistance of the bony pelvis to stresses (see Fig. 381). The three bones comprising the pelvis, ilium, pubis and ischium unite about the acetabulum

By eight centres { *Three primary (Ilium, Ischium, and Pubis)* / *Five secondary* }

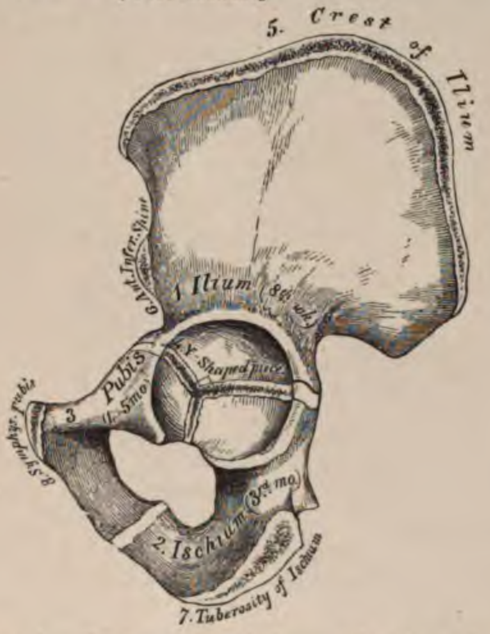


Fig. 382.—Plan of ossification of the hip bone. The three primary centres unite through a Y-shaped piece about puberty. Epiphyses appear about puberty, and unite about twenty-fifth year. (Gray.)

to form that cavity. The centres of ossification unite as described in Fig. 382.

Frequency.—Bruns states that fractures of the pelvis equal about 0.3 per cent. of all fractures. When both the true pelvis or ring fractures and the false pelvis fractures of the ilium are counted, this percentage is raised. Many are never diagnosed. Some patients die of other injuries, and the pelvis fracture is not enumerated. In the series of 11,302 fractures investigated at the Cook County Hospital, pelvic fractures were found 76 times in the eight-year period embraced in those figures. This is equivalent to 0.67 per cent. In 1914 there

were 12 pelvic fractures, 6 of the pubic bone, 3 of which were of both rami, 4 of the ilium, 1 being of both sides simultaneously; 1 of the pelvic ring in several places, and 1 of the ischium accompanied by a break in the pubic ramus. Out of 12 fractures there was but one death, that being the case of the multiple fractures of the pelvic ring.

The usual cause of these injuries is direct violence, which must be severe, because the bones give way only to great force. Indirect violence may be a cause when the force is transmitted through the ischium by falls in a sitting posture, or transmitted through the acetabulum from the legs in falls on the feet. The direct violence of squeezing between the old-fashioned bumpers and hand couplings of railroad cars was a frequent cause. Crushing injuries of the pelvis caused by falling earth or timbers, or slides of caved-in excavations, or by the patient rolling between a fixed and movable body, such as

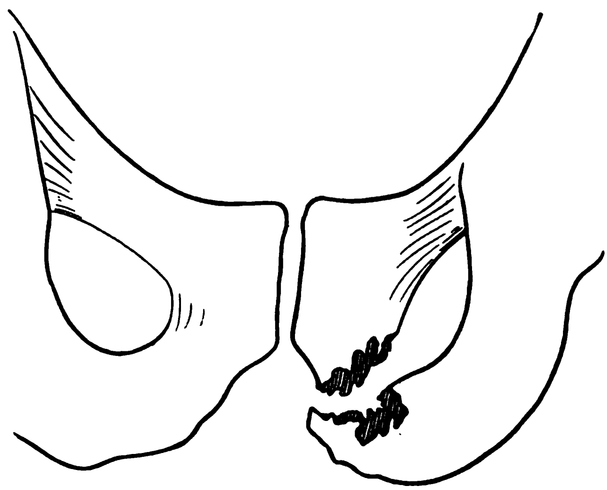


Fig. 383.—Fracture of the inferior pubic ramus with little displacement. Seen from behind.

a boat and a pier or a railroad car and a platform, are found. The trauma may act from several directions, and there are consequently any number of displacements.

Pathology.—In anteroposterior crushing the pubic rami on one or both sides generally break first, and if the separation is not great and the trauma ceases, no important displacement occurs (Figs. 383 and 384). If the force continues, the wings of the pelvis are spread apart, and the sacro-iliac joints are either dislocated through a giving way of the ligaments, or if they hold, suffer a fracture near the articulation (Fig. 385). Owen[1] recorded a case in a woman aged thirty-nine years who attempted suicide by jumping from a window. The pelvic rami on both sides were fractured, the left sacro-iliac synchondrosis was

[1] Kentucky Med. Jour., xii, No. 12, p. 378.

separated, the labia were lacerated, and yet the bladder and urethra were intact.

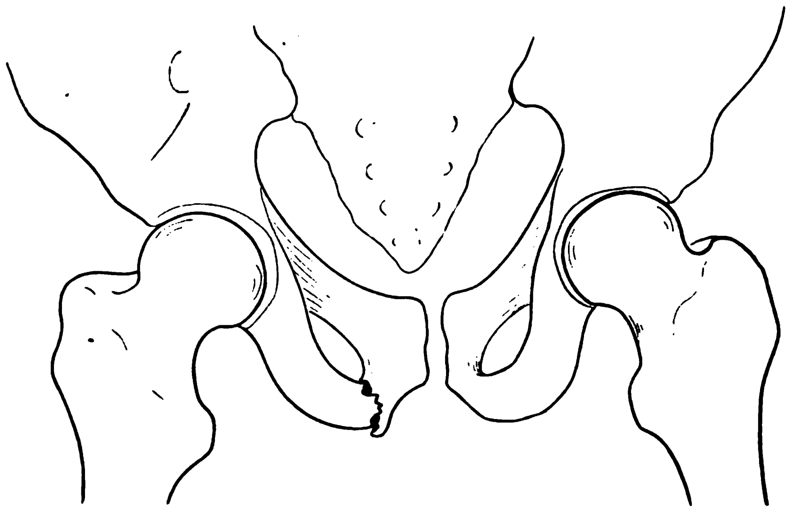


FIG. 384.—Fracture of the inferior pubic ramus.

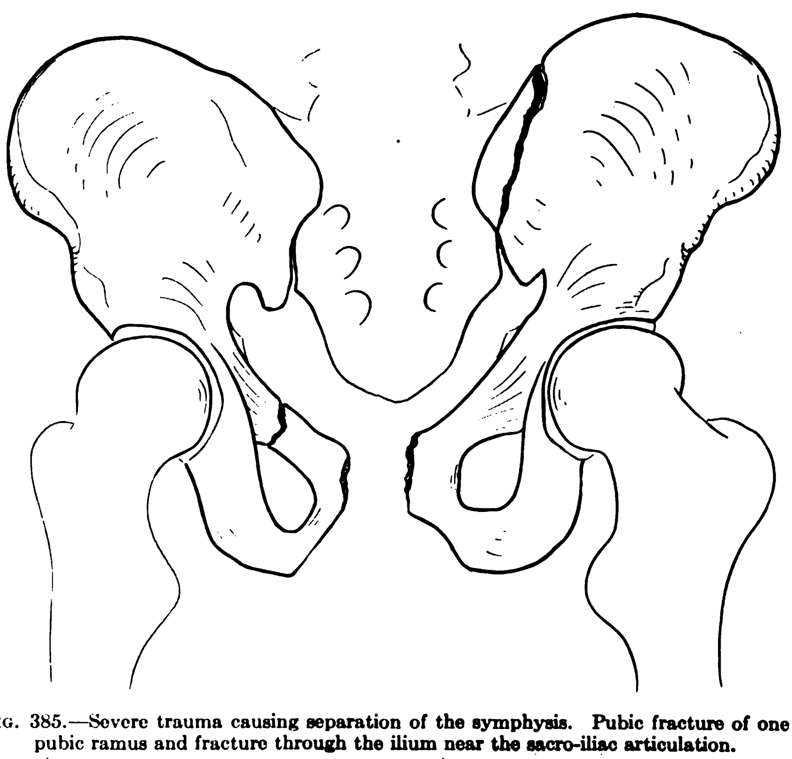


FIG. 385.—Severe trauma causing separation of the symphysis. Pubic fracture of one pubic ramus and fracture through the ilium near the sacro-iliac articulation.

Double vertical fracture of the pelvis was described by Malgaigne, This is caused by force received on the greater trochanter of the femur, the side of the pelvis or the leg, transmitted upward. The acetabulum may be cracked, but the two lines of fracture are commonly one in front in the pubis and the other in the rear through the ilium, posterior to the acetabulum. This lateral fragment may be pushed upward and dislocated out of position (Fig. 386). For fractures of the acetabulum see paragraph dealing therewith.

Malgaigne's fracture may involve the sacrum itself, running diagonally through the sacro-iliac joint in part. This may be caused by a falling and striking on one side of the pelvis and the ischium at the

Fig. 386.—Malgaigne type of double vertical pelvic fracture in a child. The lateral portion of the pelvis is pushed up out of place.

same time, as the fracture is rarely bilateral. If the broken-out area is displaced upward, or laterally, the leg and hip motion on that side are limited, there is apparent but no real shortening, and palpation can usually discover the displacement. The broadening of the front or the narrowing of the rear of the pelvis may be seen at first glance.

Displacement is not often great, and the severity of the injury does not depend on the amount of displacement so much as on the site of fracture. It must also be understood that displacement found after accident may represent only a small portion of the displacement at the exact moment of injury, because the pelvis may have sprung back into shape. Within the last year at the Cook County Hospital I saw

a double vertical fracture in which the leg on the affected side had three inches apparent shortening, arising from the great upward displacement of the whole side of the pelvis. The patient had no symptoms of complications except a little obturator nerve pain down the inner side of one thigh, and after a week's rest on a modified Bradford frame he became so irked by the confinement that he demanded crutches and walked home. Other cases with little palpable displacement have ended fatally from severe complications, especially those which involve the bladder and urethra. Anteroposterior compression and fracture are likely to injure the bladder and lateral force to injure the urethra.[1] When the pubes are violently separated, the urethra is torn across at its ligamentous attachment, and an extravasation of blood and urine follows in the scrotum and perineum. The space of Retzius is invaded in extraperitoneal rupture of the bladder. Blood and urine point upward, following the fascial planes, to show in the inguinal region as ecchymoses or soggy edema. The rough edge of bone, after the pubic separation, may rupture the iliac vessels. Gerster[2] reported a case which showed laceration of the common iliac artery. He also cited a case of left-sided pelvic fracture in a female which did not result in direct injury of the urethra, but which caused compression of the urethra by a blood-clot so that the catheter had to be used for sixteen days.

Bladder injury may consist in a contusion and hemorrhagic infiltration of the wall or complete rupture, which is either intra- or extraperitoneal. Extraperitoneal rupture usually involves Retzius's space, and the retroperitoneal area. Intraperitoneal or intra-abdominal rupture is also found, especially when the bladder is full at the time of accident and is deprived of its bony protection by the pubis. The tear in the bladder is often transverse and the mucous membrane may pout out of the wound into the abdomen. I have seen such a tear four inches long. Rarely the wound instead of being clear cut is lacerated and jagged.

Urine and blood extravasations become quickly infected, even when drained. Necrosis of the tissues develops. After urethral rupture rarely a localized abscess in the perineum forms.

The psoas muscle spreads out over the ilium and may be traumatized and contused. Bone fragments may penetrate it or a hematoma form in its body. These cause pain when the leg on that side is raised and may be a valuable sign in diagnosing obscure fractures.

There are severe complications in some cases and in addition to the signs of fracture of the pelvis there is often evidence of shock. Complications involving the urethra are manifested by marked desire to urinate with no results; a catheter passed into the bladder may fail to reach the cavity, if the laceration is at the base, and a few drops of bloody urine alone will be evacuated. If the bladder cavity is entered, there may be a few ounces of bloody urine withdrawn. It is

[1] Sherman, Ann. of Surg., lii, 143.

[2] Ann. of Surg., lii.

joints, and the displacement of the sacrum. These are all caused by extreme violence and are of little interest clinically, as death usually follows in a few hours in spite of any treatment (Fig. 388).

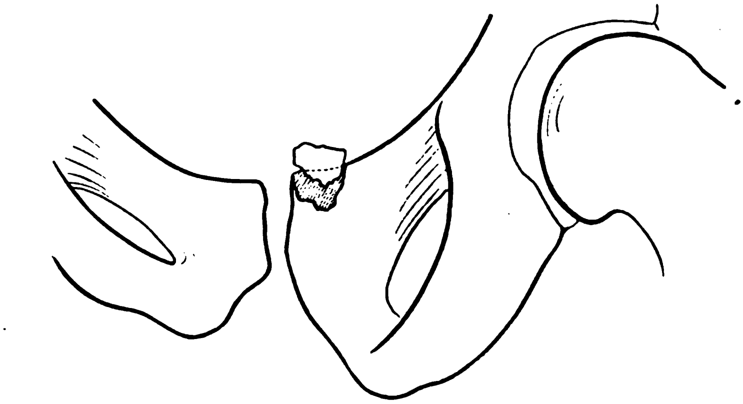


Fig. 388.—Fracture of the pubic bone near the symphysis caused by direct violence.

Symptoms and Diagnosis.—Pain, localized at the points of fracture, or when the pelvic girdle is compressed between the two hands or rocked up and down is an important symptom. Crepitus is thus demonstrated in a small proportion of cases, or is felt by the patient when he is turned over. Ecchymotic spots in the groin and perineum and edema of extravasated fluids are helpful findings (Fig. 389).

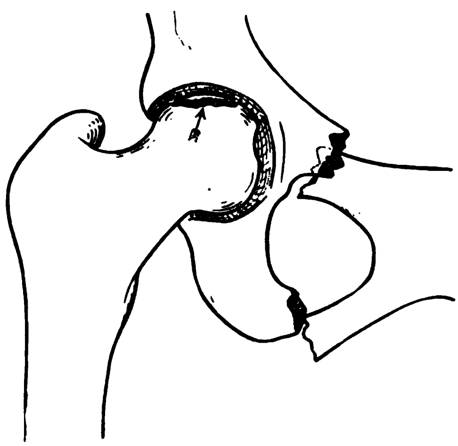


Fig. 389.—Fracture of the pubic rami with fracture of the head of the femur.

Walking may be possible but painful and accompanied by muscle spasm in the legs and thighs. If the displacement is noticeable, there may be apparent leg shortening or palpable changes in the pubic contour.

Symptoms of the complications depend on the abdominal, urinary and rectal findings. Rapidly increasing dulness in the flanks or lower abdomen within the first twelve hours after injury indicates intraperitoneal rupture of the bladder and peritonitis. Hemorrhage is differentiated by signs of greater shock. Perineal and scrotal swelling of urinary extravasation which follow injury of the bulbous portion of the urethra takes twelve to eighteen hours to develop. Extravasation of blood and urine into the groins and pubic regions indicates extraperitoneal rupture of the bladder or urethral injury back of the triangular ligament. The time of onset of this sign depends on the amount of urine in the bladder at the time of accident, but it is usually slower than the perineal swelling.

When the sacro-iliac joint is displaced, the posterior iliac spine is raised or depressed and may be dislocated laterally compared to the opposite side. In the double vertical fracture, if the broken-out piece is widely dislocated, it may be movable by direct manipulation or by traction on the leg. Sometimes it is so securely impacted that no ordinary force will move it, and it should be left *in situ* unless there are nerve pressure symptoms. These conditions of fracture and dislocation must be differentiated from simple sacro-iliac strain or possibly traumatic sciatic-nerve injury or tuberculosis of the sacro-iliac synchondrosis. If the pubis is held fixed and there is freedom of motion and lack of muscle spasm in the back, tuberculous conditions in the spine and hip can be eliminated. Sacro-iliac strain usually gives localized soreness over the joint involved, which is promptly relieved by snug binding. The roentgenogram is also very helpful in deciding displacements and possible fractures after falls.

Course and Prognosis.—These depend largely on the complications. As previously stated, in 12 cases at the Cook County Hospital, in 1914, there was but 1 death, that in a severe multiple fracture. The simple fractures of one ramus, or of parts of the false pelvis, tend to heal quickly, generally with some deformity. Complicated cases with visceral lesions have a mortality of about 50 per cent., and the immediate prognosis depends on the character of these complications and the promptness of treatment. Eight cases were reported by Sabin;[1] 2 complicated cases died, and the 6 others recovered, although 2 were accompanied by urethral damage, 1 by abscess, and 1 by bladder rupture. The iliac crest was injured in 2 cases.

Treatment.—Treatment depends on the character of the fracture and displacement and the complications. Simple cases with no complications may be reduced by gentle manipulation or traction on a leg. I have never been able to perform this manipulation successfully but once. If much force or mechanical extension is necessary to make reduction, the deformity should not be interfered with. The patient should be put at rest in bed or on a Bradford frame with the canvas raised just above the mattress. A firm swathe or adhesive-

[1] Northwest Med., 1914, M. S., vi, 159.

plaster binding can be applied from trochanter to trochanter. This often increases rather than diminishes the pain in the early hours after injury, more relief coming from the Bradford frame. Buck's extension may be applied to both legs and the head of the frame lowered. Open fractures are treated as directed in the chapter covering them; as a rule the injuries are so severe that attention is directed immediately to the complications.

It is wise to have the patient urinate as soon after pelvic injury as he is seen, or if he is unable to do so, a catheter should be used to determine the condition of the urethra and bladder. If a small amount of bloody fluid is obtained before the bladder is reached, the urethra is torn across or lacerated. When the urine is returned bloody and in small amounts, rupture of the bladder is suspected. Under no circumstances do I believe it wise to introduce a measured amount of sterile fluid to ascertain when proportion can be returned by the catheter. False information may be obtained, or increased danger of peritonitis from the rupture and bladder may follow. For similar reasons enemata should not be given even when the rectum is not suspected of injury. When bladder or urethral ruptures are seriously suspected, operation should be done *at once*. Probably less than one-half of 1 per cent. of bladder ruptures recover spontaneously. If there is urethral rupture, and perineal extravasation is manifested, free opening by perineal section should be made and drainage from the bladder provided for by a catheter inserted in the proximal urethral opening, if it can be found, or by free incision into the bladder. Rubber strips must drain the perivesical space. A catheter may be introduced into the whole length of the urethra when bladder drainage is provided for, with a view to early healing and restoration of urethral continuity. Some authors advise immediate suture of the torn urethral ends when they are exposed in the perineal section. The cases are rare in which this can be done, and it is as good practice in deep ruptures to be sure of bladder and tissue drainage, depending on later operation after recovery for attention to the urethra. More distal tears or partial ruptures through the urethral wall are sutured successfully.

Free fluid in the abdomen, shock, and lack of urine call for suprapubic operation. If the bladder is ruptured, it must be closed by a double row of sutures, and drainage from the peritoneal cavity must be provided. Torn vessels, nerves, and other abdominal lesions are cared for in accordance with general surgical principles.

Traumatic lesions of the sacro-iliac joint alone are frequently met with. These can be divided into (1) sprains, (2) relaxations or subluxations and (3) true dislocations. The sprains are temporary in character, occurring mostly in women during pregnancy or menstruation, in positions of extreme flexion, or following attempts to lift heavy weights. Men sustain sprains from falls or slight crushing accidents. They are diagnosed by the local pain and tenderness, pain referred to the point where the pelvis is jarred or compressed, the negative roentgenogram, and the therapeutic test of strapping which gives relief.

Subluxations and true dislocations are caused by direct or indirect violence. Roberts[1] described a case in a twenty-one-year-old man who was crushed in a car accident. There was pain in the back, hip, and epigastrium. A roentgenogram showed a subluxation which was reduced under anesthesia. There was no feeling of crepitus, but the reduction was accompanied by a sensation like that imparted by the return of a ball-and-socket joint. Two similar cases were reported by Ashhurst at the same time. The legs show an equal length and thus rule out hip-joint injury.

The treatment is rest and strapping after reduction. In severe cases of "sciatic scoliosis" where the nerve pain is due to the subluxation, it is better to use a plaster spica after reduction. Other references: Chapman[2] and McClure.[3]

A case of dislocation of the ilium with separation of the symphysis pubis was reported by Young.[4] The accident was caused by the patient leaning forward and lifting a heavy piece of timber. After six months, a fifteen-pound weight applied for ten days was of no effect, and as the Roentgen picture showed the condition, anesthesia was given and a reduction made by traction. A subsequent picture demonstrated a restoration to normal.

FRACTURES OF THE ACETABULUM, INCLUDING CENTRAL (INTRAPELVIC) DISLOCATIONS OF THE HEAD OF THE FEMUR.

These fractures are divided into:

(1) Fractures of the rim of the acetabulum.

(2) Radiating fracture of the acetabulum, including fracture of the floor and epiphyseal separation.

(3) Penetrating fractures with or without intrapelvic displacement of the head of the femur.

Fractures of the Rim of the Acetabulum.—Fractures of the rim of the acetabulum most frequently accompany dislocation of the femoral head. They may occur without dislocation, sometimes with splits in the head or a chipping out of small fragments. Extent of the rim fractures varies. The upper and posterior portion is the usual site of fracture, and the area broken off may be in one piece or several. Avulsion of the capsular ligament may tear off a small shell of bone.

When not connected with dislocation, the condition may be undiagnosed even if a roentgenogram is made. In obscure cases, as stated under Fractures of the Head of the Femur, dried Roentgen pictures of both hip-joints, taken in the same position, must be studied. Dislocations and fracture of the femoral head may be differentiated by the relative position of the leg and thigh, a flexion and inward rotation

[1] Ann. of Surg., vii, 754.
[2] Southern Med. Jour., July, 1914.
[3] Northwest Med., June, 1914.
[4] Univ. Penn. Clinic for Am. Orthop. Assn., June, 1813; Tr. Am. Jour. Orthop. Surg., xii, No. 2.

in dislocation, and an eversion and extension in fracture. After reduction of dislocation a crepitus may be felt from a loose fragment of the rim, or the femur may easily slip out of place. Crile reported a case in which nearly one-half the acetabular rim was broken off at the base.[1]

Pain and soreness in the hip-joint are the constant symptoms. Because of these, use of the joint is restricted, and partial ankylosis is likely to follow. This arises from one of two conditions or from their combination. Pain and lack of use in the joint cause a shrinking of the capsule and a stiffness of the periarticular tissues and muscles. Between the fragment and the pelvis callus or exostoses may form, which inhibit free motion and use of the joint.

Treatment.—The treatment consists in the immobilizing of the hip in a plaster spica in abduction, for three or four weeks, and then the starting of progressive use which is persisted in if not painful. If use distresses the patient, it is better to reimmobilize for another month. When ankylosis develops in the joint, breaking up of adhesions under anesthesia is of no assistance; the curative treatment rests in an open operation and an arthroplasty after removal of the excess callus and misplaced bone. Recent cases after dislocation which will not remain reduced may be subjected to open operation and the loose fragments nailed into place or removed.

Radiating Acetabular Fractures.—Radiating acetabular fractures, including fractures of the floor and epiphyseal separation, arise from violence received on the trochanter or on the leg and transmitted to the pelvis. The cracks may run into all three of the pubic bones, or be confined quite closely to the acetabulum itself. The pubic portion is more likely to be broken clear through and suffer displacement, while the iliac and ischial portions are simply split slightly. The patient may be able to walk after the accident, always with pain, weight being supported on the intact portion of the acetabulum. If there has been a sinking in of the whole acetabular area, the trochanteric region will be flattened, abduction limited, and the whole leg a little shortened.

Neuhof[2] believes that there are few museum specimens that show any possibility of complete or partial separation of the epiphysis of the three bones uniting in the acetabulum.[3] He reports the first case of acetabular separation of juvenile pelvic bones, unassociated with other pelvic lesions. The child was a six-and-a-half-year-old girl, who fell on her hip. There was painful walking, a slightly less prominent trochanter, and a fuller Scarpa's triangle on the injured side. Rectal examination usually shows tenderness on the affected side; pressure on the trochanter toward the joint or compression of the pelvis is painful.

Treatment.—The treatment consists in a plaster spica applied with the leg in abduction, as given previously.[4]

[1] Ann. of Surg., xiii, 373.
[2] Ibid., lx, 367.
[3] Poland, "Traumatic Separation of the Epiphyses," 1898.
[4] Kontorowitch, Contrib. à l'étude de Fract. du Bassin. Fract. simp. et limitée de la cavité cotyloide. Thèse de Lyon, 1903; Grube, Rev. de Chir., 1904, xxix, 60; Thevenot, Rev. de Chir., February, 1904; Thevenot, Rev. de Orthop., March, 1904.

Intrapelvic displacement of the femoral head or central dislocation of the femur results from the same causes with a greater degree of, and more prolonged, violence. The displacements may be of two kinds. The head of the femur is pushed in through the cotyloid cavity, carrying the bottom of the acetabular bone before it, or, more commonly, the floor of the acetabulum is split through and the femoral head and neck driven into the pelvis. Abduction probably favors this dislocation fracture, because in falls on the feet, the thicker upper portion of the acetabulum resists the force, but if abduction is present, the thinner pubic portion bears the brunt of the punch. Muscular force and contraction may prevent reduction (see Fig. 390). This dislocation requires great violence, and a severe injury is apparent. Usually the trochanter has become sunken. Hip movements are possible but painful and restricted, depending on the size of the hole

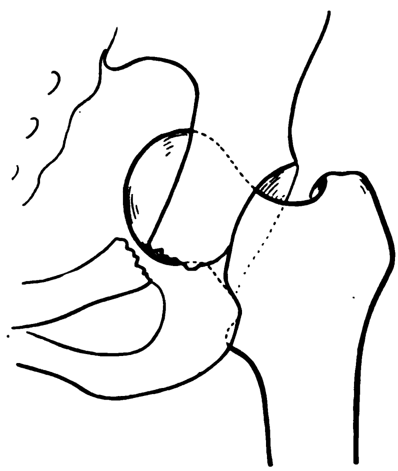


Fig. 390.—Penetrating fracture of the acetabulum by the femoral head. Central or intrapelvic dislocation of the head of the femur with fracture of the pubic ramus.

punched in the pelvis. Crepitus is usually present in the hip. The leg is in eversion and there is shortening, varying from one to two inches. Rectal and vaginal examination permit palpation of the displaced head of the femur. Abdominal tenderness is also present. The associated injuries may be very severe and quickly fatal. Injury of the rectum and bladder and urethra, or rupture of the iliac vessels are reported. On the other hand, the symptoms may all be lacking except the finding of displacement, and the patient may be able to walk and work at once. Adams[1] reported one case of this kind, the roentgenogram confirming the displacement and making the diagnosis positive. Four cases with pictures have been recently reported by Ewald.[2]

[1] Boston Med. and Surg. Jour., 1907, 432.
[2] Ztschr. f. orthop. Chir., xxxiii, Heft 3-4.

Course: Use, especially when not painful, can cause a new socket to develop around the displaced head and function becomes satisfactory in spite of the leg shortening. Ankylosis also develops. The mortality is 50 per cent., 22 out of 44 cases mentioned by Fuller,[1] and is largely due to the associated injuries. In uncomplicated cases the prognosis is quite favorable. Schiller's case went undiagnosed for 11 months, and was ankylosed in flexion, abduction, and outward rotation.[2]

Differential diagnosis must be made between this condition and fracture of the femoral neck with impaction or erosion, and the dislocations of the hip. Hamilton says this can be done by the finding of crepitus as soon as the leg is moved, while in neck fractures with separation, crepitus does not occur until the fragments are brought into apposition. In the anterior dislocation of the head of the femur it can be seen and felt, in the dorsal dislocation, the trochanter lies above Nélaton's line and the thigh is flexed and adducted, and in thyroid dislocations the leg is lengthened.

Treatment.—In uncomplicated cases reduction can often be made under anesthesia by lateral traction, the possibility of reduction depending on the size of the hole punched out. The pelvis is firmly fixed by means of bandaging and pressure by assistants, and the lateral pull on the thigh is made by the operator until the femoral neck is felt slip out (Fig. 391). If the hole is large and the muscles are powerful, strong tendency to recurrence may exist. In such a case the possibility of resecting the head of the femur by open operation will present itself. This is done to avoid ankylosis or pressure.

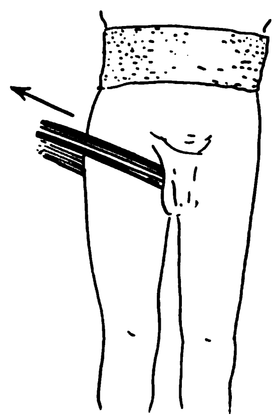


Fig. 391.—Method of reducing central dislocation of the hip. (After Cotton.)

Loepp[3] reports a case of central dislocation in a forty-year-old man who fell five feet and landed on his right hip. The right leg was rotated outward, flexed and abducted and was 3½ cm. shorter than the left. There was a puckering of the skin over the greater trochanter which was drawn nearer the middle line. Reduction was made by means of extension and lateral pull on the thigh but no crepitus was noted, probably because of the size of the hole in the pelvis. The femur tended to slip back again into displacement when traction ceased, so the leg was placed in extension with a weight of twenty pounds hung on. Catheterization was necessary, but there was no blood in the

[1] Am. Jour. Med. Sci., 1911, cxli, 385.
[2] Moore, Med. Chir. Tr., xxxiv, 107; Arreger, Deutsch. Ztschr. f. Chir., lxxi; Schloffer, Arch. f. klin. Chir., lxxxiv, 499; Womers, Beitr. z. klin .Chir., lii, 185; Schroeder, Northwest Univ. Med. School Quart. Bull., 1912.
[3] Arch. f. klin. Chir., Bd. cii, 1092.

urine. The final result showed 1½ cm. shortening, the head of the femur was in the acetabulum and all movements of the hip except adduction were good. Extension should remain on the leg about three months, and the subsequent use of the leg should be light for three more months.

The complications of bladder and bowel rupture or hemorrhage are treated by immediate open operation.

FRACTURES AND DISLOCATIONS OF THE SACRUM.

Longitudinal cracks and fissures have been discussed. They are rare. Dislocations of the sacrum from opening of the sacro-iliac joints are rare and caused by great violence. Most cases are fatal. Other injuries often accompanying them. Diagnosis is made on external and internal vaginal and rectal examination. If reduction can be made by digital pressure within the rectum or vagina, that should be done, and the patient should be put on a water bed or Bradford frame with soft pads to avoid pressure necrosis in the sacral area. If complete dislocation is present, paralysis of bladder, rectum, and the legs would be present from injury of the sacral plexus. Stimson reported a case.

Transverse fractures of the sacrum are caused by falls on that area or a blow or kick from behind. The usual displacement is that of the lower fragment forward into the pelvis, with a line of separation just below the sacro-iliac joint. Oblique fractures are very rare, and Roentgen-ray study is revealing an increasing number of incomplete cracks and fissures.

Sloughing of the sacral tissues, interference with bladder and rectal action on account of injury of the sacral plexus and other intrapelvic pathology, which goes with pelvic fracture, may be complications.

Symptoms.—The symptoms are great pain in the sacral region, displacement of the bone fragment, and visceral disturbances. Examination externally and *via* rectum or vagina demonstrates the misplaced bone or the extreme tenderness of linear cracks. Coughing, defecation or even breathing are painful, and the fragment can be moved by the finger in the rectum. Nerve injury corresponds to that found in dislocations.

Treatment.—Treatment is similar to that of dislocation of the sacrum. Attempts to pad the fragments into position by a rectal or vaginal packing are not successful and always cause intense pain and run the risk of causing necrosis of the walls. It is impracticable to pack the rectum and allow drainage through a tube for the escape of excreta. Open operation for the fixing of the sacrum in position when reposition fails to hold the displaced fragments has not been reported, but it is feasible.

FRACTURES AND DISLOCATIONS OF THE COCCYX.

These are rare, and reports of verified cases are not frequent. Women are more frequently concerned than men. Most cases arise from falls on a sharp edge, as on a child's block or across a fence. They may also follow trauma of horseback riding or, as in one case I have seen, be caused by the jar sustained by the patient riding on the "scenic railway" in an amusement park. Dislocations of the coccyx are also frequent in obstetrical practice. When the pelvic joints become softened prior to the time of labor, dislocations of the coccygeal portion may arise from slight trauma or muscular action. I have seen one case in which there was no history of trauma and which could be accounted for in no other way than by muscular action. During the passage of the child's head these dislocations are also seen. Whether there is a true fracture at the sacrococcygeal junction or a stretching of the ligaments which permits the displacement has not been decided. The symptoms are pain in the coccygeal region, increased by pressure or even by sitting or lying on the back. Defecation is also painful, as the bone is usually displaced forward. In traumatic cases there may be ecchymoses or swelling found externally in the coccygeal area. Complete dislocation may be forward, backward, or lateral. The former is the most frequent; backward or lateral displacements are rare and are due to some special trauma. Pain is severe immediately after the trauma and radiates down the inner side of the thighs. In obstetrical cases, those which occur before labor in the later months of pregnancy may cause great uneasiness and by constant irritation make life miserable for the patient. Dislocations occurring during labor may go unnoticed for several days or weeks, until the patient gets up and walks.

Diagnosis.—Diagnosis is made on the external evidence of swelling and ecchymoses with pain on pressure in acute traumatic cases. Lateral fracture dislocation can be detected by the finding of the loose and painful fragment on one side of the gluteal fold in a swollen area. Posterior and anterior displacements are recognized by external examination aided by a finger in the rectum or vagina. The displaced fragment is usually freely movable and examination extremely painful in recent cases. Disturbances of sensation are found when the sacral plexus is involved. Bladder and rectal action may also be interfered with. The patient may be unable to lie on the back, or even sit on padded cushions, or pneumatic rings, preferring to lie on the side. Osteo-arthritis may develop and lead to a condition of chronic or constant pain which shatters the patient's general health and leads to narcotic habits, great constipation, and mental disturbance. "Coccygodynia" is the term applied to these painful conditions which follow any of the previously mentioned causes.

Treatment.—In recent traumatic cases the fragment may be replaced by a finger in the rectum or vagina and pain greatly alleviated. Hot applications, anodynes and rest are indicated until acute effects

subside. If the pain and distress continue and coccygodynia is diagnosed, the only permanent relief which can be promised is from operative removal of the coccyx. As a rule the cases in obstetrical conditions become well after replacement and rest.[1]

Operation is performed through a midline posterior incision, the bone being separated and the fragment removed by dissection through the sacrococcygeal junction. Relief is due to the severance of the coccygeal nerves or their release from pressure by the misplaced bone. The operation requires rigid asepsis and a semiprone position during healing of the wound.

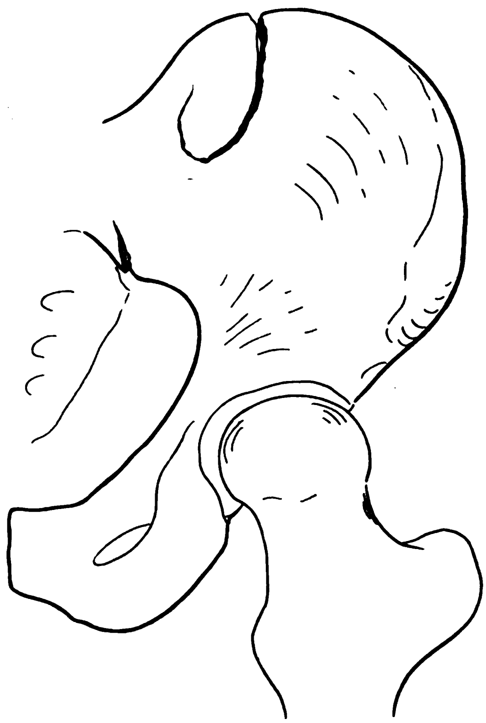


FIG. 392.—Incomplete fracture of the wing of the ilium.

FRACTURES OF THE ILIUM.

Fractures of the ilium involving the crest and spines, and not involving the pelvic ring, are due to direct violence and muscular action. Hamilton recorded a case of fracture of the posterior superior spine caused by a fall on the back. Direct violence of falls, where the iliac crest strikes the ground or knocks against a heavy object, causes a separation of a whole or a part of the edge of the crest. A small area, usually triangular in shape, may be loosened and driven in toward

[1] Haurant and Pigache, Rev. de Chir., January, 1914, xxxiv, No. 1.

the abdominal cavity. In children the upper epiphyses for the crest may separate, but this is not an extensive displacement on account of the wide attachment of the abdominal muscles, the internal and external oblique and transversalis, which tend to hold the broken fragment in position. If these muscles are torn loose at the time of accident, the displacement is greater and the fragment is usually pulled upward (see Fig. 392).

The anterosuperior and inferior spines are broken off by direct violence of a sharp blow. The displacement is not great, and the condition may not be recognized. Fracture of the anterosuperior

FIG. 393.—Fracture of the anterosuperior iliac spine by muscular action.

spine caused by muscular action is very interesting. The literature contains but six or eight cases, but I believe the condition is fairly common (see Fig. 393). They may be caused by heavy weights falling on the tense abdomen and striking the anterior iliac spines or exerting a tearing-out stress on the muscles attached on the bony point, or sprain fractures from muscular action of the thigh group. Cases have been reported by Ruppert[1] and Skillern[2] and others. Sprain fractures are rare and happen when the patient is running. There is sharp pain in the anterosuperior iliac spine and patient generally has to stop.

[1] Wien. klin. Wchnschr., 1914, xxvii, 700.
[2] Ann. of Surg., lvii, 289.

In Skillern's case the patient was able to run five yards, the accident happening as a race was finished. Attached to the spine are the gluteus medius, the tensor fascia lata, and the sartorius. The first two muscles are internal rotators of the leg, and the sartorius is a pronator of the knee. The mechanism is probably as follows: in running, the leg involved is stretched way out behind as a step is being taken with the opposite leg. The ground may give way or the foot slips, so that simultaneously with the hyperextension an outward rotation of the leg takes place. This passes the limit of extension permitted in the hip-joint, and the spine is pulled off by the muscles named.

Diagnosis.—Diagnosis is made by the pain on the crest or spine, by deformity of local displacement, and by crepitus of loose fragments. Loss of function varies. If the spines are involved, there may be inability to walk. When the crests are ruptured, abdominal pain and tenderness often predominate. Hyperextension of the thigh will cause pain in the spines or crest.

Course and Prognosis.—Crushing weights on the abdomen may cause death from complications. Fractures and displacements of the crest or epiphysis usually unite by bony union in four to six weeks. Permanent deformity, arising from a flaring out or drooping of the crest involved, may be found after union. Rarely fractures of the anterior superior spine, which are not given rest, fail to unite and there is found a loose, painless fragment after many weeks. I have seen one case of this character after an injury in a football game. The usual result is bony union.

Treatment.—Treatment consists in strapping of the pelvis or in application of a plaster-of-Paris cast to immobilize the pelvis and both thighs to the knees. This should be left on at least four weeks. Fractures of the anterior spines demand immobilization of the leg on the affected side in extension, or in very slight displacements, the fragment can be held in position by strapping. If a large corner is broken off, it can be nailed on with a cigar-box nail.

CHAPTER XXII.

FRACTURES OF THE FEMUR.

FROM January, 1907, to May, 1914, at the Cook County Hospital, Chicago, out of a total of 10,702 fractures, 999, or 9.3 per cent., were of the femur. Stimson shows in his statistics from the Hudson Street Hospital in New York City, 540 fractures of the femur, a percentage of 3.7. Statistics of former collections by other authors also give a lower percentage than that obtained at the County Hospital, a circumstance which may be attributed to the two following facts: that the more recent figures cover the use of the Roentgen rays in traumata and that on account of crowding in the hospital, cases of fracture of minor importance are dressed and turned away without record, and of those kept in as patients the proportion of injured femora is large. It may also be said that relatively few cases of dislocation of the femur are received, because of improved diagnosis by the Roentgen rays, and that older records which gave a relatively higher percentage of dislocation, could they have been searched by the Roentgen rays as now, would reveal far fewer dislocations and more instances of fracture.

Anatomy.—The femur, the longest bone in the body and most important as the link between the trunk and leg is also a lever much like the humerus. Its movements at the hip are somewhat more restricted than those of the humerus at the shoulder, but its ball-and-socket joint permits a wide range. At the upper end the neck is attached at about an angle of 130 degrees. The angle of inclination (cervical angle or femoral angle) is formed by two lines, one through the longitudinal axis of the shaft, the other through the long axis of the neck, and is normally 125 to 130 degrees. Hoffa's line through the base of the neck, perpendicular to the long axis, extended, meets the extended long axis of the femur in an angle called Alsberg's angle, or angle of direction, which varies in normal limits from 41 to 44 degrees.[1]

Hip Joint.—The head, held to the acetabulum by the ligamentum teres, is covered by the strong divisions of the capsular ligament, those fibers arising from the ischium behind, from the ilium above, and the pubic ramus in front, uniting in a long, strong insertion in the linea trochanterica in front. No attachment is afforded these at the base of the femoral neck posteriorly. The joint synovial capsule is inserted near the base of the neck and is reflected on the neck, head of the bone and ligamentum teres, to its insertion in the acetabulum and ligamentum transversum acetabuli, leaving a part of the neck, which,

[1] Tubby, British Med. Jour., July 25, 1908.

while intracapsular, is outside of the joint. In front the capsular ligament covers the whole neck, the attachment being about three-fourths inch in front of the intertrochanteric line.

Knee-joint.—The stability of the knee-joint depends largely on the crucial ligaments, the extrinsic ligaments and muscles, as the bone surfaces are not closely adapted to each other and much motion is necessary. On the outer side is the external lateral ligament, strengthened by the biceps femoris tendon, extending from the external tuberosity of the femur to the head of the fibula to be attached between the two heads of this tendon. Many knees, according to

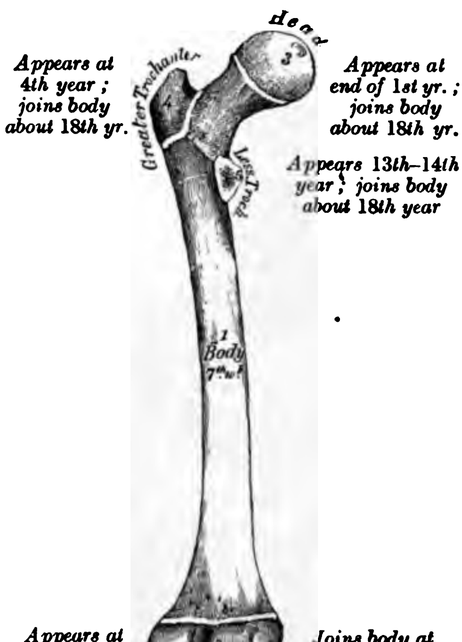


Fig. 394.—Plan of ossification of the femur. From five centres. (Gray.)

Jones,[1] show also a shorter posterior band of this ligament. The capsule of the joint proper is a separate structure, and the external ligament is also separated from the external semilunar cartilage by the tendon and bursa of the popliteus.

The internal lateral ligament is a long, fan-shaped, fibrous structure of great importance to the joint, its deep fibers intermingling with the true capsule and becoming attached to the internal semilunar cartilage. To make this insertion and blend with the transverse fibers of the cartilage, the deep fibers have to turn in toward the joint,

[1] Ann. of Surg., l, No. 6, p. 969.

and as a consequence are much shorter than those found on the outer side of the knee. The lateral ligaments are assisted by the presence of the disks of the semilunar cartilages, which are crescentic in shape, thicker at the convex margin, thinning out on the concave side. By means of their wedge shape each cartilage supports the action of the opposite lateral ligament in resisting lateral movements of the leg, and also aids in making the crucial ligaments tense.

At the neck, the angulation of attachment may vary, even in the same individual, as has been shown by many roentgenograms. This difference may lead to a slight real shortening of one leg, which is not

Fig. 395.—Longitudinal section of head and neck of femur. (Gray.)

noticed when the leg is undiseased and no trauma has included the part, because the pelvis tips enough to equalize the difference and gives no apparent shortening. Traumata of the hips in infants and children mechanically cause angular variations, impactions, or axial changes, without causing enough disability to be regarded as more than a bruise.[1]

Structure.—Ossification takes place from five centres, for plan of which refer to Fig. 394. The structure of the body of the femur is that of a

[1] Savariand, Bull. et mem. Soc., de Chir. de Paris, 1914, N. S., xl, 406.

cylinder of compact tissue, in which the large medullary canal lies. The wall is strongest and thickest and assumes almost a triangular shape near the middle of the shaft, where the medullary canal is small and very distinct. At the ends of the bone the compact layer becomes thinner and the medullary canal smaller until it is filled with cancellous tissue. The structure is of great importance in connection with fracture of the upper and lower ends of this bone. At the ends, the lamellæ or truss rods of support inside are placed in the lines of greatest pressure. In the neck they are arranged as Gothic arches; chief lamellæ at right angles to the articular surface run together to form a strong central bone wedge which lies in the neck and extends out to the epiphyseal line, being supported in the head itself by lamellæ extending to the sides of the neck along both upper and lower borders. Force applied to the head is transmitted along this central bone wedge and on down

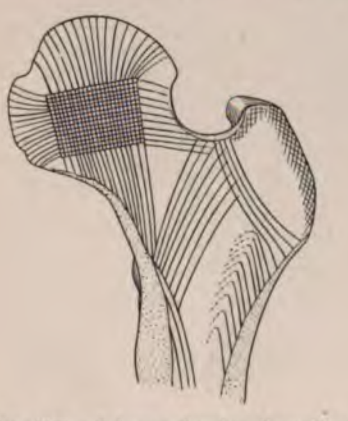


Fig. 396.—Scheme showing disposition of principal cancellous lamellæ in upper extremity of femur. (Gray.)

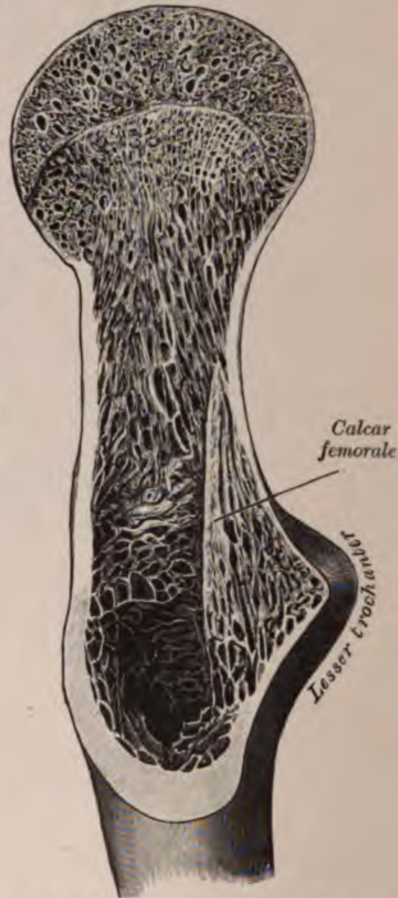


Fig. 397.—Oblique section of upper extremity of femur showing calcar femorale. (Gray.)

to the body of the bone, spreading out over these strong truss-like bands. In addition there are two supporting bars, one from the lesser trochanter to the superior border of the neck, and the other across the union of the greater trochanter with the femoral neck (Figs. 395 and 396). The neck also contains a vertical plate of bone, the calcar femorale (Fig. 397), as described by Bigelow, which reinforces it and passes down below the trochanters to take origin from the

centre of the medulla. At the lower end the strong lamellæ pass down perpendicularly to the knee-joint and are crossed at nearly right angles by planes of cancellous tissue.

FRACTURES OF THE UPPER END OF THE FEMUR.

Fractures of the Head.—These fractures are rare and may be classed as follows:

(1) Crushing, either in connection with fracture of the acetabulum and central dislocation, or by impact against the acetabular rim, or an exostosis as reported by Stimson.[1]

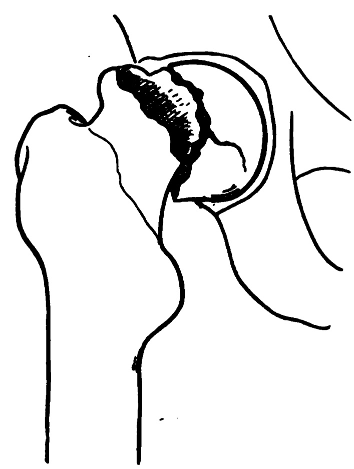


Fig. 398.—Linear fracture of the head and fracture of the neck. The position of eversion of the leg is apparent from the displacement of the neck.

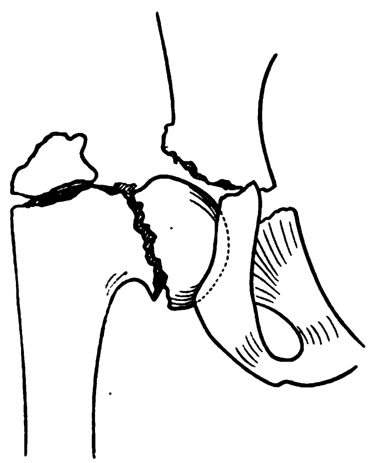


Fig. 399.—Fissure through the epiphysis of the femoral neck with little separation. The tip of the greater trochanter has been fractured through its epiphysis and the acetabular wall is punctured. Cause, direct violence on the hip.

(2) Linear cracks, with or without separation, and frequently from the base of the ligamentum teres down the long axis of the neck (Fig. 398).

(3) Tearing off of a small fragment by the pulling out of the ligamentum teres, or direct violence against the acetabular edge.

Careful roentgenograms, as the technic of exposure for the hip-joint has improved, have shown these smaller fractures. If the crushed portion is not displaced and does not interfere with joint motion, no treatment is indicated, but if the displaced fragments cause pain or limit motion, removal may be indicated. If completely detached these fragments eventually become smoothed off like a sesamoid, or gradually absorbed (see Fig. 399).

[1] New York Med. Jour., August, 1889, p. 163.

Fractures of the Neck of the Femur—These may involve any part of the neck but usually are near the head, or near the trochanters at the base. They are classified as follows:

(1) There may be fissures or incomplete cracks accompanied or not by bending of the neck, shortening of neck and leg, or other change in the neck. Hamilton (*Fractures and Dislocations*) thought these fractures were improbable, but Colles[1] considered that three out of eight cases seen by him were complete. It is now established by the Roentgen-ray examinations that these are found, and the joint capsule or periosteum may be torn or not. The presence of fracture depends on the cause, the amount of force, and the individual's age, governed by the lines of deposition of the majority of the lamellæ in the neck.

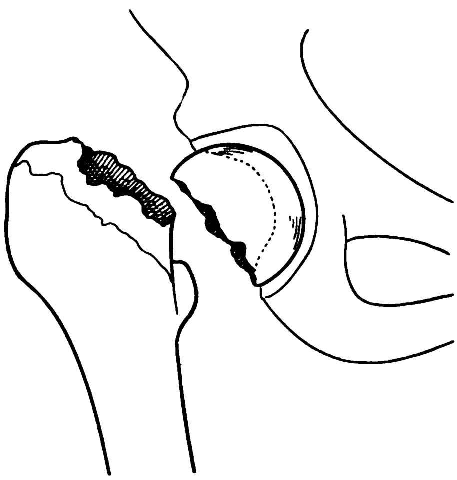


Fig. 400. — Fracture high up through the femoral neck. Absorption of both fragments by attrition and displacement upward of the shaft.

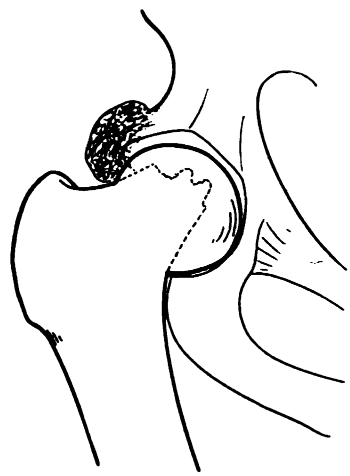


Fig. 401.—Fracture of the femoral neck with driving in of the lower fragment. Note the callus formation about the acetabular edge which probably denotes fracture there. This bony growth greatly restricted motion in the joint.

(2) Fractures of the neck just below the head are common (Fig. 400). Complete fracture with or without separation with slipping of the neck up on to the ilium, occurs. If the neck passes upward, shortening of the leg, outward or inward rotation may be found. If the fracture force divides into such directions that part of its plane extends in the direction of the longitudinal axis of the neck, as in falls on the buttock or trochanter, impaction follows the driving of the neck into the head fragment (Figs. 401 and 402). The question of the value of impaction can be settled on a rational basis if one bears the following facts in mind: When the fragments are impacted all teaching has been to leave them alone and not destroy the impaction for fear of

[1] Dublin Hosp. Rep., ii, 339.

removing the blood supply from the head and thus causing its necrosis, or at least causing delayed or fibrous union. The author believes impaction has little bearing on the prognosis of these two points, and is of little importance except in old persons, when it has value in promoting or holding bony continuity. In the young and in adults, proper reduction is of more importance than impaction, and if this cannot be accomplished without destroying the latter, impaction should not be considered at all. To illustrate, if an impacted fracture of the neck occurs in a young adult with unfavorable position of the leg, or shortening, the impaction should be broken up and the leg brought into proper position to favor full ultimate return of function without shortening.[1]

The viability of the head does not rest on impaction of the neck into it, but depends on the integrity of the vessels which supply the

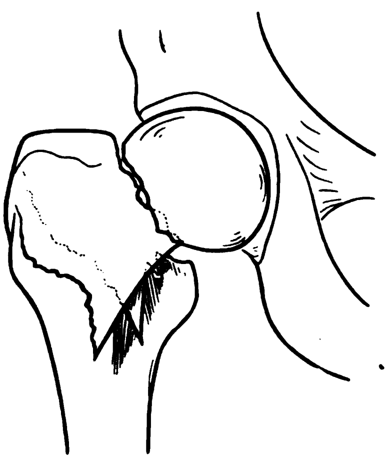


FIG. 402.—Fracture of the neck and also through the trochanteric line, the latter being impacted.

head. These arrive by way of the capsular insertion into the periosteum of the head, so that viability of the head fragment is a question of their injury or thrombosis from extensive laceration of the capsule rather than fracture of the bone tissue. If the function of these vessels is destroyed, late necrosis of the head follows.

Formerly it was supposed that fractures of the neck were found only in elderly people due to slight trips or falls on account of the rarefying of the bones incident to age and a change in the axis of the neck of the femur. Walker[2] states that the condition is a senile osteoporosis which is caused by disease of the vascular walls supplying the neck. This causes bone weakness, the cortex becomes thinner, some of the lamellæ of the spongiosa are absorbed, and fracture more easily results, so that a slight trauma or twist in an adult is all that is needed.

[1] Jones, Proc. Roy. Med. Soc., December, 1910.
[2] Ann. of Surg., xlvii, 84.

Of his 112 cases, 51 over sixty years of age were caused by a slip or fall on the floor or sidewalk, and 28 cases to falls from a ladder or scaffold, or downstairs; 18 cases caused by falls from a height, loft, elevator, etc., were all under fifty years of age.

(3) There may be fracture of the neck and separation of the upper epiphysis in children.

Whitman[1] reported 18 cases of fracture of the neck in children all under eight years of age seen by him in ten years. These cases differ from those of elderly people in that helplessness and persistent disability are not present. The conclusion is reached after a few days, because the child can walk, even though a limp and some pain are present, that the trauma caused merely a contusion. Careful examination would show, however, actual shortening of one-half to three-fourths inch, with a corresponding elevation of the trochanter, which is usually found displaced forward, toward the anterior superior iliac spine. Slight outward rotation is common. Some lameness and discomfort may last for months because of slow interrupted bone repair, and extreme motions of the hip-joint are painful. This contrasts with the condition of fracture of the neck in old people in whom the disability is immediate and prolonged. In childhood the disability is short, the return to functional use very quick, if not immediate, but the femoral neck has been weakened and placed in a new position subject to greater strain in weight-bearing which leads to actual shortening, limp and disability later. Albee[2] quotes Rotch as saying that the Amazons used to separate the upper femoral epiphyses of their male infants to promote their own supremacy, so lasting was the resulting disability. Diagnosis is not made early unless recourse to roentgen ray is had. The symptoms continuing are likely to progress into a coxa vara, or simple depression of the neck, predisposing to continued deformity. Late diagnosis with a differentiation from tuberculous coxitis is forced. Walker finds that there were 9 cases in his series under thirty years of age. Whitman later details 10 cases of this fracture in children seen three weeks to six months after the accident, all of which had been diagnosed as hip disease. He reiterates the following points of diagnosis differentiating from tuberculosis:

(1) The child has been previously in sound health.

(2) In cases of fracture the trochanter is elevated; there is a change of hip contour on account of the approximation of the trochanter to the anterosuperior spine, and the leg is shortened and everted.

(3) Late cases give a history of limp subsequent to some trauma, pain referred to hip and knee, restricted motion at hip.

Walton[3] takes another view of this question and says that the epiphysis of the head of the bone, which joins the shaft from the eighteenth to the twentieth year, is probably more often separated in part or completely than any other epiphysis of the body. The

[1] Ann. of Surg., 1900, xxxi, 145. [2] Am. Jour. Orthop. Surg., viii, 602.
[3] Fractures and Separated Epiphyses, 1910.

question of the site of injury, however, is debatable because of the fact that sudden violence applied to the femur is more apt to cause bending of the neck than a separation at the better protected and stronger epiphysis within the capsular structures. If fracture occurred at the epiphyseal line involving in part the articular surfaces, and separation of fragments was such that three-fourths inch shortening resulted, the joint function would be greatly impaired at once by the bony irregularity or later by callus thrown out. Great force is needed such as could be applied to the epiphysis only by means of projecting processes to which muscles and ligaments are attached, but this epiphysis is less liable to this leverage than any in the body.

The truth probably lies midway between these views, and there seems to be no reason why the epiphysis of the thin neck of the femur, exposed to the severe strains of the body weight, should not give in an analogous manner to the epiphysis in other parts of the body, notably in the radius, as I have demonstrated.[1] Similar cases are recorded by Albee[2] who cared for one, a girl aged thirteen years, and a year later had her referred back to him by a colleague as a case of tuberculosis. A second case in an eighteen-year-old male, the separation having occurred four years before, had the limp as the only symptom, and the roentgenogram showed the flattened head with the epiphysis displaced and firmly united with the projecting corners worn off. Bruns, in 100 epiphyseal separations, found but 1 of this kind.[3] As mentioned, however, the disability is not immediate in children, many walking away from the scene of their fall or accident. Hence, as is found by the Roentgen-ray examination, the neck suffers later. At the meeting of the American Orthopedic Association Bolton demonstrated this theory by the presentation of an anatomical specimen removed from a boy of eight years who fell six stories and failed to obtain any union in four weeks; at the same time Meyers and Stan showed similar specimens removed at autopsy. Sprengel[4] disagrees with Whitman and reports two cases of epiphyseal separation in adolescents aged seventeen and eighteen years. This is refuted by the argument that it is not true that the epiphyseal line is a weak one and that separation through it is more common than fracture; because if this point is weak it is more so in adolescence than in childhood before the external cartilage and resistant periosteal cover have diminished to nearly an adult condition. Contributary causes are rickets, septicemia, syphilis, starvation, scurvy and prolonged mercurial treatment. In adolescents we should expect epiphyseal separation to be caused by slight violence. Schwarz,[5] writing on the question of spontaneous epiphyseal separation in children (intracapsular), records 3 cases of such separation following several months to a year after fracture of the neck of the femur, in which bony union and good function had been established. The epiphyseal separations occurred

[1] Surg., Gynec. and Obst., August, 1913, p. 241.
[2] Loc. cit.
[3] Arch. f. klin. Chir., xxvii, 24.
[4] Ibid., 1898, Band xlvii, S. 805.
[5] Beitr. z. klin. Chir., Tübingen, 1913, lxxxvii, 709.

without known severe trauma and were ascribed to a rarefying process taking place after the child began to use the limb. These cases were all under observation and were checked by examination and roentgenograms. Schwarz's article contains an excellent bibliography on the subject up to that time. The epiphyseal cartilage and area in young children are proportionately thicker and larger than the shaft of the femur, as all the head and neck structures are first one cartilaginous mass, so that this mass, to quote Albee, acts as a "shock absorber" and is less liable to disruption. Traumata followed by dislocation in the adult lead often to epiphyseal separation in the adolescent.

Fracture of the femoral neck in childhood is practically then traumatic coxa vara. The first symptoms are after slight trauma compared to a more severe injury in fracture of adults, with resulting deformity at the epiphyseal line. If the shortening is very little and the trochanter not prominent, there may be impaction. In other cases the femoral neck is depressed downward and backward. Disability is slight or absent, and it is concluded that the cortical substance over the epiphyseal junction may have been broken and the newly formed bone beneath has gradually yielded after use. Immediate diagnosis should be made, and the neck replaced in normal position by traction and fixation in extreme abduction and inward rotation in plaster of Paris, with inhibition or weight-bearing until the bone is firm. Supervision looking toward avoidance of long periods of standing or violent exercise must be made, and prognosis as to final position in cases seen late, with deformity already present, or if the deformity progresses, should be guarded. It is desirable to change the cervical axis, but further depression of the neck can be avoided by the use of an ambulatory splint or a perineal crotch worn for six months to take weight off the neck. When the depression has changed the angle from its normal 130 degrees to nearly a right angle the tendency to further descent until the trochanter rests on the ilium is very great. Cuneiform osteotomy offers the only hope of permanent cure of the deformity.

Tubby calls attention[1] to an opposite condition, coxa valga, the traumatic form of which follows fracture of the neck of the femur, impaction, malunion, or separation of the epiphysis. In coxa valga the limb is abducted with external rotation and limitation of adduction, the hip-joint is painful, the gait rolling and unsteady with a limp, the trunk being inclined toward the affected side. The striking symptom is a lengthening of the limb of 2 to 3 cm. Treatment consists in fixing the limb in plaster in adduction or performing cuneiform osteotomy to straighten it.

In adults fracture at the base of the neck is more frequent than near the head, and both involve the joint structures as mentioned above (Figs. 403 and 404). The former distinction of intra- and extracapsular fracture is being dropped. It has little significance other than

[1] British Med. Jour., July 25, 1908.

the placement, by the trauma of accident or subsequent manipulation, of fragments of joint structures between the broken bone resulting in delayed or non-union. The displacement may be very little. The neck can slip well up posteriorly drawn by the glutei, rectus femoris and hamstring muscles beyond the head fragment, which remains in the acetabulum, or may be impacted to any degree. Cracks or separation with diverging lines of fracture into the trochanter at times accompany this form.

Mechanism.—These fractures are caused by direct violence, acting on the greater trochanter in most cases as a smashing blow on the hip or a fall.

Pathology.—The posterior part of the neck and greater trochanter are weaker and less protected by ligamentous structures and consequently suffer the most crushing and mashing. The head fragment is

Fig. 403.—Fracture of the neck near the head. The neck fragment is in its customary position turned forward to permit eversion of the leg.

Fig. 404.—Fracture of the neck near the base. The femur is also rotated outward a little.

driven into this crushed mass of bone, the neck is shortened, and the angle of its axis is changed relative to its position on the femoral shaft in either plane, the apex of the angle being directed upward and forward. The line of fracture may be in any of the usual directions, most frequently transverse with serrations, or be limited to part of the neck only, the unbroken part preserving its continuity and periosteum intact, but undoubtedly bending (Figs. 405, 406, and 407). In cases of wide separation of fragments with shortening of the limb, complete bony rupture is found, perhaps subsequent to an impaction in the first part of the trauma. The periosteum may be completely severed with resulting necrosis of the head, as explained, or it may remain attached in one of several shreds, their width varying up to one-third the total of the periosteal covering.

At first, shortening may be little, but in a few days on account of

the tonic spasm of the muscles trying to hold the hip immobile, to avoid pain, the lower fragment is pulled up. Attempts at reduction

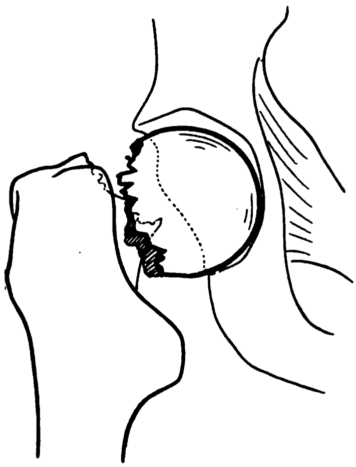


Fig. 405. — Complete transverse fracture at the base of the femoral neck. There is a little shortening in this case.

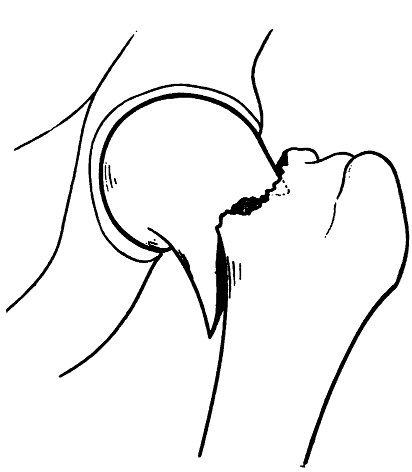


Fig. 406.—Fracture at the base of the neck with upward displacement of the shaft and consequent shortening. Slight impaction.

which loosen the fragments, or complete loss of capsular tone because of laceration and hemorrhage, will aid this shortening. If weight-bearing is allowed in fractures at the base of the neck before the callus can withstand the strain a slow process of shortening follows

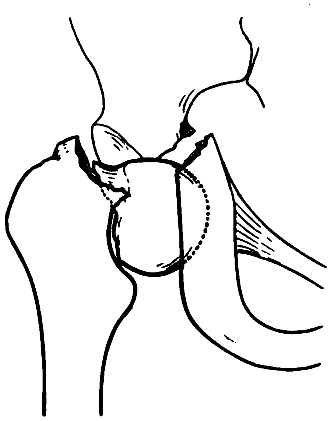


Fig. 407.—Fracture of the base of the neck with shortening, impaction and accompanying fracture of the pelvis. Cause, direct violence on the hip.

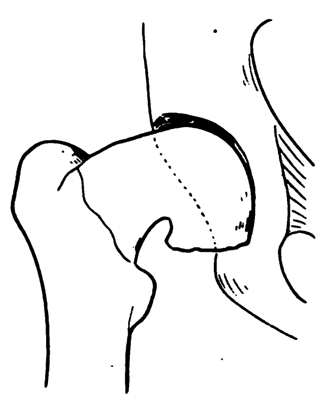


Fig. 408.—Slow bending of the neck after a healed fracture. The angle is approaching 90 degrees and there is a condition of coxa valga.

the bending of the neck (Fig. 408). If the trochanteric fragments have been separated and are numerous, the large callus can interfere

with joint action, restricting it. Breaks in the neck near the head are likely to allow less callus formation on account of their protected position and freedom of complication of trochanter damage.

Fractures at the base of the neck into the trochanter are frequent and are the class formerly described as extracapsular fracture. The displacements are about the same as in fractures higher up on the neck, and in some cases, on account of the direction of the force applied on the trochanter, the shaft fragment is rotated inward and displaced backward so that the leg lies in inversion (Figs. 409 and 410). The greater trochanter may be severely comminuted, large fragments

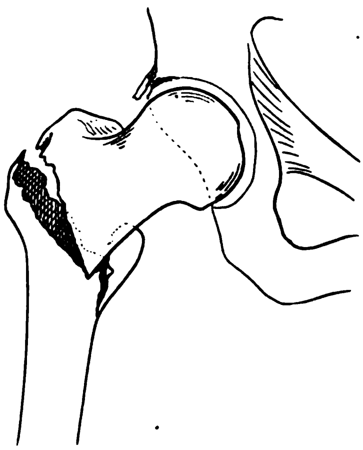


FIG. 409. — Fracture through the trochanteric line (Kocher), the leg evidently lies in eversion and the lesser trochanter is split, a common accompaniment. The rim of the acetabulum has also been splintered, probably by impaction of the head fragment.

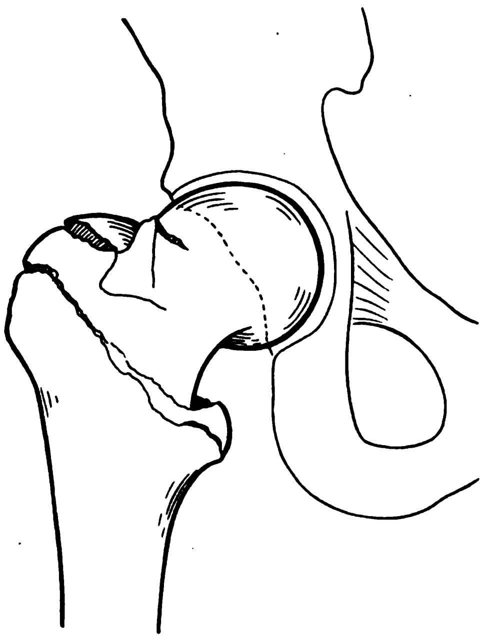


FIG. 410.—Incomplete fracture of the neck and slightly impacted fracture through the trochanteric line. The great trochanter is comminuted.

can be loosened and displaced by both violence and muscular action, or the trochanteric area can be impacted, and telescoped into itself with little axial displacement, but with shortening and other gross evidence of fracture. Every degree of injury from radiating cracks, violent tearing out of the whole trochanter and wide displacement of fragments is found, depending on the quantity, direction of the force, and the position in which the limb was at the time of trauma. Some portion of these injuries will surely involve the joint structure so that the sharp distinction of extra- and intracapsular fracture cannot be made and lacks clinical demarcation of value.

Ashhurst[1] believes that fracture of the neck at the junction with the greater trochanter is an uncomplicated fracture through the trochanter. As fractures through the trochanter are usually comminuted, violence applied to the trochanter major produces an impacted fracture through the neck and trochanter which was formerly called extracapsular of the neck. The cancellous tissue of the greater trochanter is split by the firm wedge of bone in the neck, its wedging being responsible for two or three secondary fractures complicating the primary break (Figs. 411, 412, and 413).

Cope[2] describes three distinct injuries in this region: (1) Primary fracture at the junction of the head and neck, the base of the neck being then thrust through into the cancellous tissue of the greater

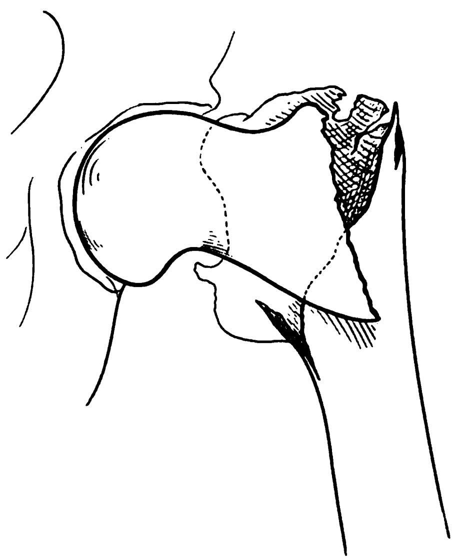


Fig. 411.—Intertrochanteric fracture with displacement upward of the shaft. The neck fragment is correspondingly tilted up and the leg shortened.

trochanter, with secondary but incomplete fracture through the trochanter; (2) separation of the trochanter due to pressure from the firm tissue of the neck. The tip of the greater trochanter is nearly always drawn inward toward the upper acetabular rim; (3) a further stage when the lesser trochanter and a slice of the shaft also split off. Ashhurst adopts this classification, adding a fourth condition, fractures below the trochanter, either transverse or oblique, which merge into (3).

Repair.—What percentage of fractures of the femoral neck result in bony union? It is impossible to say unless known cases were followed to their death and postmortem examination made of the

[1] Ann. of Surgery, lviii, 494.
[2] Treatise on Fractures and Dislocation of Joints, 1822, pp. 116–151.

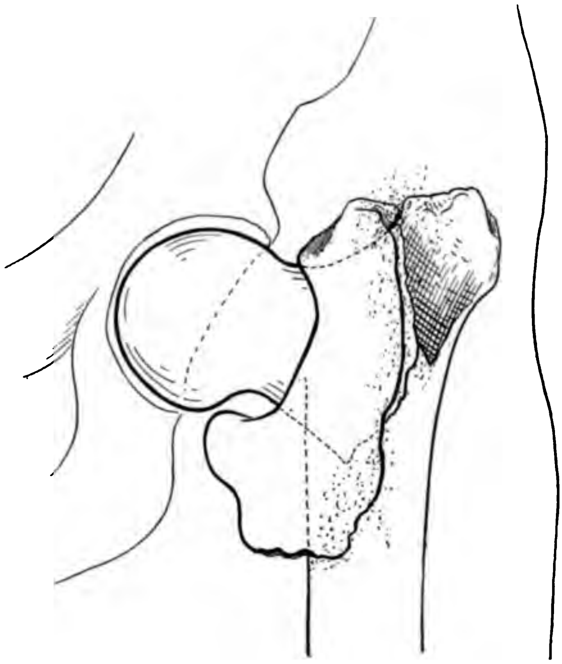


FIG. 412.—Comminuted and impacted trochanteric fracture. A large fragment has been torn off the anterior surface and the neck is impacted into the shaft.

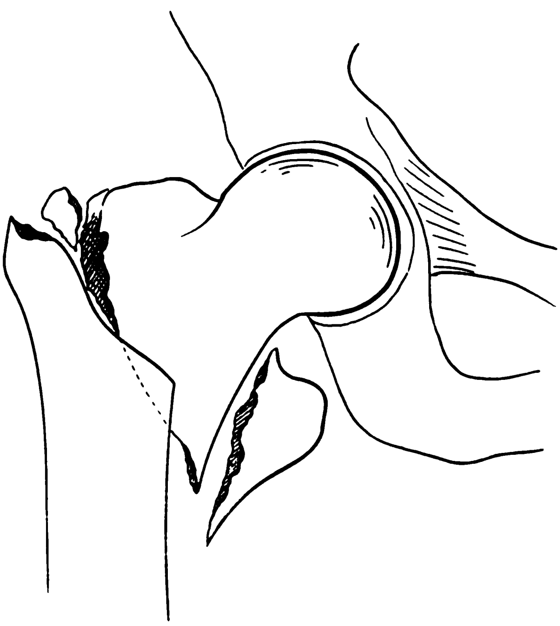


FIG. 413.—Trochanteric fracture with separation and complete splitting off of the lesser trochanter.

bone, but there are many specimens on record and in museums which show firm bony union which had lasted for years. Ruth,[1] describing the Phillips-Maxwell method of treatment, showed several specimens obtained after death. Bony union is claimed by him for all cases, and his specimens, some obtained not more than four weeks after the trauma, showed every evidence of bony consolidation. This method is dealt with fully under the head of treatment of this fracture (Figs. 414 and 415).

On the other hand, there are many cases of non-union, fibrous union, false joints, death of the head of the bone, and even suppurative and hyperplastic forms of arthritis which preclude bony union. In

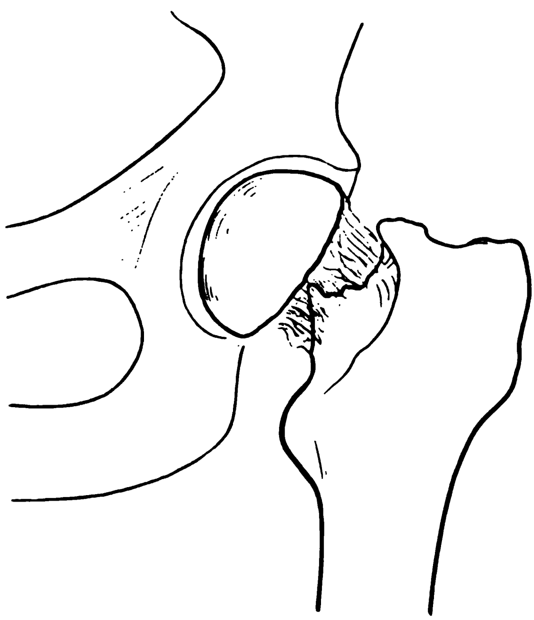


Fig. 414.—Fibrous union following fracture of the neck. Although there has been absorption of the bone of both fragments, the neck being absorbed down to the acetabular edge, there is not much shortening because the patient had not yet walked.

adults up to middle age I believe bony union, or at least such union as is serviceable and cannot be distinguished from bony union, is the rule. In children practically all cases result in bony union with little interference with growth and an obliteration of deformity as age increases. Union of a fibrous character which is strong enough to allow weight-bearing function in the leg is satisfactory in many cases (Fig. 416). Particularly is this true in elderly people from the practical standpoint. We must consider this fracture as a solution of bony continuity, and if solid union can be obtained, every effort should be made to get it even at some discomfort to the patient. In the old

[1] Albany Med. Ann., January, 1913.

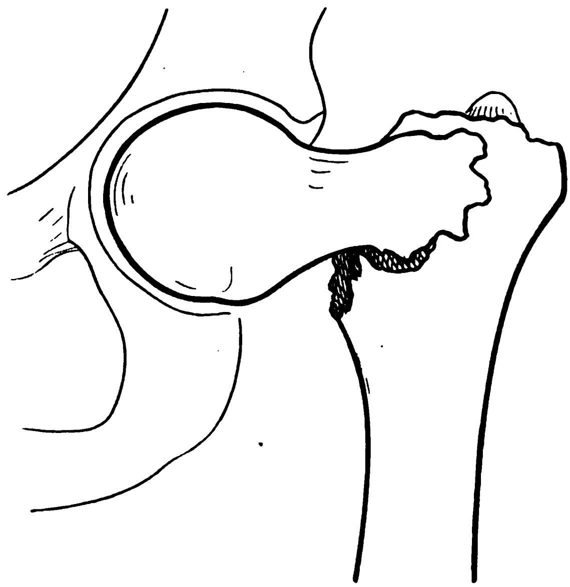


FIG. 415.—An unusual form of the trochanteric fracture which healed by bony union. The patient was allowed to walk too soon with secondary displacement and shortening. Note the neck angle.

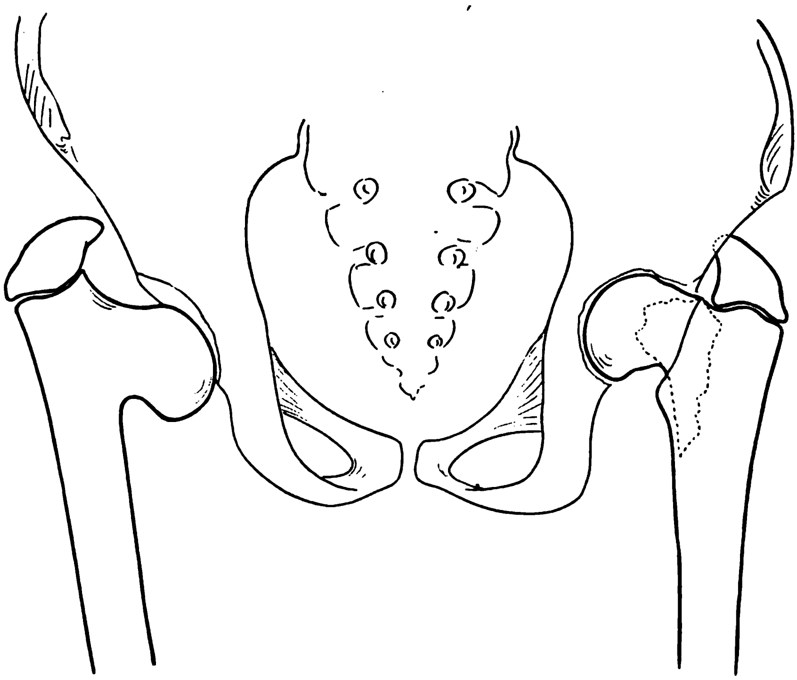


FIG. 416.—Fracture of one femur at base of the neck and traumatic coxa vara on the other side in a child.

we are rather inclined to be slipshod in treatment, anticipating failure of union, on account of age and less vigorous bones and on account of the fear of applying extension and splints with the immobilization they demand. Decubitus ulcers, a delayed pneumonia, or a hypostatic congestion of the lungs, have been considered first; hence, many cases of non-union or fibrous union are to be found. I have seen many femoral heads removed after five to eight weeks of such nondescript treatment because no union developed, and while functional results were fair after their removal, they probably would not be equal to a bony union to a retained head. Instances of impaction with shortening in adults, roentgenograms of which betray angularity and distinct line of fracture, on open operation within a few weeks after accident show bony union, not firm, but such as will later become firm. I have operated on several of these to obtain better length of the limb by means of the mechanical extension and various methods of fixation. Frangenheim[1] found that the periosteal covering of the neck was very inactive osteogenetically and that when bony union followed fractures of the neck the callus arose in most part from the cancellous bone, complete ossification not following before one year. Absorption of this bone may occur even in impacted cases and is due, I believe, entirely to vascular disturbances from the thrombosis of bloodvessels. If early motion is allowed or imperfect immobilization used, it is easy to believe that fresh sprouts of bloodvessels and osteoblastic columns from the cancellous bone become discouraged and fibrous or non-union takes place. At times also, a vigorous callus is thrust out and bony union inaugurated, but because of faulty treatment, too early weight-bearing, or imperative ambulatory care, before calcification of the new bone can follow, the use of the limb causes a retrograde process of absorption, and a fibrous union is the outcome. Instances are on record where the whole neck has been absorbed, leaving the head free and a false joint between it and the shaft.

If all cases could be put in anatomical apposition and given a fair chance for bony union, there would be less complication of this phase of the fracture. For the reasons given and the exigences of immediate health, in a large number of cases anatomical reposition and retention are not faithfully sought. The fracture may not be recognized at all, and it can be truthfully said that the character of the repair is so varied and so unsatisfactory because an opportunity is not given to solicit bony union through the placing of the fragments in apposition. Cervical fractures take longer to heal than any others of the body. The necessity for use and movement of the hip and body in daily demands interferes seriously with correct repair, and the long stay in bed and confinement mitigate a happy result. The repair effort takes place in large part from the lower fragment, the upper fragment being able to do little more than hold its own viability because of its nutrition. To refer again to impaction, its

[1] Deutsch. Ztschr. f. Chir., 1906, lxxxiii, 40.

value is twofold especially in elderly people. It absolutely holds the fragments in apposition. Treatment of the impacted cases is always of the most gentle sort with every regard *not* to break it up, because observations shows that ununited fractures result in this region so frequently. As much care should be taken to bring unimpacted fragments into apposition as is taken to *hold* the impacted ends together, and better results will be observed. Murphy[1] calls attention to the fact that fewer cases of femoral neck fractures would give poor results if they had been immobilized in abduction, or nailed, to obtain primary union without shortening or absorption, and believes that the friction of the neck on the head fragment where immobilization is short, imperfect, and followed by use, leads to an absorption process. Evidence is shown in a case followed for two years and four months, of much absorption, the neck disappearing completely out to the shaft and only a small button of bone remaining in the acetabulum. This disappearance is largley a matter of blood supply and mobilization, for absorption in the epiphyseal area characteristically takes place from within outward.

Ashhurst and Newell[2] traced 21 cases of fracture of the neck after three years and found that 62 per cent. of them had entirely useful limbs. Cotton[3] says that non-union in fracture of the neck is not rare in cases showing impaction at first, as this frequently gives way and there follows some bone absorption, even if associated only with the repair process. Fracture in the trochanteric region almost invariably unites with bone, often with great deformity and disability therefrom, whereas fracture higher up on the neck, if solidly impacted, unites with shortening and more or less deformity of eversion, giving fair clinical results.

Imperfect impactions which tend to perpetuate the deformity give also fair results unless loosened. In loose fractures, which are really accidental incidences of non-impaction, there is no bony union, but a serviceable fibrous union often results.

Unrecognized cases, contusions of the hip, and persistent limping and pain in children should be more carefully investigated and diagnosed with the Roentgen rays as an adjunct used as freely as a white blood count is employed in intra-abdominal differentiations. Careful searching of dried plates of these cases will show many passed over fractures, and there will be less interstitial absorption of the neck and rarefying osteitis observed. When the neck is absorbed and use of the limb is made, pressure gradually forces the shaft up onto the dorsum ilii, and the body weight is carried by the Y-ligament with much pain and disturbance. Lane denies the existence of these conditions when anatomical approximation is made.

After the base of the neck is broken and splits extend into the trochanteric area with separations and elevations of the periosteum,

[1] Clinics of Dr. J. B. Murphy, ii, 16.
[2] Ann. of Surg., xlviii, 748.
[3] Boston Med. and Surg. Jour., clxx, 719.

an abundant callus is found. The new bone fills in the areas of blood-clot between the bone surface and the periosteum, or if the periosteum is torn, the bony outgrowth extends into the attached tendons and capsular structures. A large callus may thus form a buttress encircling the upper fragment and acetabulum, no union in the neck may be present, and yet the patient can support himself on the limb and walk comfortably. On the other hand, exostoses from this bone proliferation may extend in a manner to restrict joint motion seriously, or by extension of a periarticular thickening of the joint structures, render walking painful and limit joint motion. One such case at Mercy Hospital gave on examination all findings of a completely ankylosed joint. Roentgenogram was not decisive, but seemed to show an exostosis which on open operation was discovered to interfere with joint motion and its removal without opening the joint capsule resulted in perfect freedom of motion in the hip. Advances in bone surgery, both in mechanical and operative treatment, are greatly reducing the percentage of absolute non-unions and improving final functional results beyond hope of former times.

Repair may be further altered by constitutional disturbances or too prolonged treatment. In children excessive weight for extension may pull the trochanter below its normal level and increase Alsberg's angle so that a condition of coxa valga results, accommodated by a tipping of the pelvis when the patient becomes ambulatory. Many months—from four to ten—are needed for full bony consolidation of this fracture, and remeasurements can be made weekly after weight-bearing is started to make sure that the neck is not yielding, though function seems good and pain is absent. Premature use is thus to be checked by the use of a crutch for a few weeks and may ward off a later permanent shortening and deformity. If the hip-joint becomes the seat of low-grade arthritis or synovitis, the repair may terminate disastrously from a functional standpoint. Suppuration has been reported following hematogenous infection. Where the head is excised most cases result in shortening and stiffness in the joint caused by lack of support of the head and the periarticular changes. A new joint readily forms and fair function is enjoyed, but most cases do better with the establishment of a complete bony ankylosis from neck to pelvis which gives no motion but permits weight-bearing without pain.

Signs and Symptoms.—These different types of fracture are considered together, as many of the symptoms and signs are common to both, varying in degree only. Attention should be paid to the patient's history, especially as to previous injuries to the hip or evidence of disease there or elsewhere that may influence fracture. Tuberculosis, carcinoma, and acute infections in any part of the body, bone cysts and other pathological influence, must be borne in mind as well as the immediate history of trauma and its nature. In elderly people and children the possibility of slight violence must be carefully brought out in questioning as it is frequently a cause.

Local Trauma—Bruising and swelling of the injured hip are present when the cause is severe violence. These may be lacking entirely when the fall has been but a short distance and when the fracture followed a twisting or slip which was the real cause, the fall being secondary and checked by the patient's catching at a near-by support.

Loss of Function.—This is the most striking finding of all, for while a severe contusion on the hip can for a short time cause loss of function in the limb, it is rarely complete. In fracture in children, as stated, the loss of function may also be of short duration or entirely absent, so that they can walk away from the scene of injury. In adults or in old people this is rare indeed, and the limb is usually found slightly flexed and rotated outward and the patient can bear no weight on it nor raise it from the floor. Walker,[1] in his 112 cases, found loss of function pronounced in 94, in but few of which could the heel be brought up toward the hip. Formerly differentiation between fractures near the head (intracapsular) and those near the base (extracapsular) was built on the relative degree of loss of power. This method is liable to so many errors that it is valueless. Instances of patients being able to walk after fracture are recorded. Most probably impaction of firm enough character was present to permit it. By muscular action the patient may be able to flex the thigh on the trunk, but the knee flexes at the same time and the heel does not rise from the bed. Twice I have seen vigorous men with impacted fracture from direct violence who could raise the foot some six inches from the ground on supreme effort. Mr. Robert Jones has stated that the patient can often lift the leg from the bed in impacted fracture, and a correct diagnosis is only arrived at when spontaneous disimpaction occurs two or three weeks after the injury. In severe contusions, the limb may assume the position of fracture and be quite useless, but the disability is not so profound and a few days' delay, coupled with other findings, or the roentgenogram, will establish a diagnosis. Capsular distention from hemarthrosis cannot explain these cases, as the foot tends to assume the rotated inward position when the capsule is under slight pressure, as I have shown on the cadaver. Probably temporary muscular paralysis allows the limb's weight to roll it out.[2] The position of the limb is quite characteristic. It lies slightly flexed, abducted and rotated outward and is helpless. The foot may lie entirely on its outer surface because of gravity and relaxed muscles, and the angularity of the site of fracture. The posterior part of the neck being extracapsular and more fragile is more comminuted. A position of relaxation in resting is established with the toes turned slightly out, and with the loss of the support of the femoral neck this position is exaggerated. In cases of impaction with the trauma received when the leg is inverted the limb may not roll outward, but

[1] Loc. cit.

[2] Experiments by Speed in J. B. Murphy's contribution to Surgery, Bones, Joints and Tendons, Jour. Am. Med. Assn., 1912, lviii.

remain in a normal position or be inverted. Inversion is very rare, and the slightest manipulation unlocking fragments will cause the foot to be everted. When little eversion is present, by grasping the foot on the normal and injured side at the same time, the surgeon may remark the degree of limitation of passive inversion on the fractured leg. The upper part of the thigh appears swollen and ecchymotic, if a few days have elapsed since injury. Its fulness is more marked in fractures at the base of the neck. Shortening is apparent at a glance, even with the eversion taken into account, and it is made more noticeable by the fact that pain is constant, referred to the trochanter and upper surface of the thigh and can always be aggravated by passive motion. If the leg is supported in a comfortable position, this symptom is lacking, but very slight external movements or active attempts to move the limb cause its return, so that the patient is content to let it lie quietly.

Measurements taken during push-and-pull traction on the leg will show a difference caused by lack of firm support at the neck when it is broken.

Localized tenderness under pressure about the trochanter and hip is present. The examination by firm but pointed pressure on the groin will find a point of deep tenderness over the head. Slight jars on the heel or knee may discover great tenderness localized about the hip, but this is not very valuable evidence.

Flattening of the hip, relaxation of fascia between the great trochanter and the iliac crest is also an observation of value. Comparison must be made with the body stripped and both hip regions exposed to good light. The evidence of these signs is permitted by the shortening of the limb and the overriding of the fragments.

Crepitus is an inconstant finding, and its absence has led to many diagnostic errors in this fracture. Impaction may account for its failure to appear; interposition of small pieces of periosteum or torn capsule or the overriding of the fragments also may, when the small area of the neck is considered and the tendency for the upper fragment to tilt forward are remembered. It is dangerous to attempt to elicit it for fear of destroying impaction or working into the site of fracture muscles and other soft parts from the pressure of the iliopsoas across the line of fracture with the leg in complete extension. In obscure cases where manipulation of the hip is painful and fracture is possible crepitus should not be sought. When placing an injured hip in a comfortable position or using very slight manipulation, the surgeon may fortunately find crepitus, but it should not be searched for by extensive motions which are painful. Under anesthesia many cases believed to be impacted will give crepitus at the first gentle manipulation after relaxation. Gentle, steady extension with rotation enough to correct eversion will not often break up an impaction, but unguarded violent attempts of rotation of the limb will. The placing of the limb in a normal position by great gentleness with steady traction is quite harmless, and if it is sustained there by proper support there is less

danger of further eversion and shortening and possible breaking up of impaction.

Shortening of the limb and position of the greater trochanter are most important findings. Shortening varies from one-half inch to three inches, depending on the site of fracture, the force of the violence, presence or absence of impaction or overriding, and by alteration in the angle between neck and shaft. If the fracture lies near the head, in the early stage shortening is supposed to be little, increasing as the unopposed muscles, the recti, hamstrings, and tensor vaginæ femoris act. When the fracture is near the base of the neck and overriding is marked we should expect the maximum amount of shortening just after the injury, possibly growing less in a few hours when muscular spasm is lessened. Shortening may be small because of impaction, and suddenly or gradually become much greater when some untoward active or passive motion loosens the fragments. Tritely, the exception—which may be a lengthening of the limb—proves the rule of the general finding of shortening (Walker, 70 in 112, one-fourth to two inches). Shortening is indicated by displacement of the trochanter upward and is determined by the following measurements: First, the length of the limb as compared to its fellow member is to be ascertained. To decide this, bony points are selected as landmarks and pains are taken to place the limbs in a corresponding position in relation to the long axis of the body. If one leg lies parallel to the axis and the other is abducted, measurements will not correspond, so the limbs must be placed in symmetrical relation. A long stick or ruler is placed between the legs at right angles to another which joins the two anterior superior iliac spines, and each leg is placed to make an equal angle with this. If it is not desired to move the injured limb, although, as said, it does little harm to straighten the foot, the sound limb is moved out to make an equivalent angle. Palpation is then made to locate the anterior superior spines definitely, they are marked with ink or wet crayon, and the same markings are made on the tips of the internal malleolus and distances measured by steel tape (Fig. 417). In fat subjects it is sometimes difficult to locate the spines, or in the marking, the skin slides and the true point is lost. Practice enables one to become accurate. If a pendulous abdomen forbids use of the spines the umbilicus can be used as an upper mark, but it is less accurate. It is not to be forgotten that limbs vary in length when no trauma or fracture is to be diagnosed. Either bone of each leg may vary so that the total length of limbs is equal. Bristow[1] measured 128 cases of paired bones, 99 of which were femora, of which 78 per cent. were unequal. Wight,[2] having concluded from observation that many uninjured limbs were of different lengths, measured 60 individuals with no fracture, turning the figures on the tape down so that they could not be seen and found equal length legs in only ten instances, the varia-

[1] Ann. of Surg., l, 313.

[2] Arch. Clin. Surg., i, No. 8.

tion reaching as high as one and three-eighths inches. This finding was later confirmed by 42 additional measurements. The attainment of precision in taking measurements is a matter of much practice, and even adepts will not agree in a series of cases measured independently. Bristow mentions a series of 312 measurements made by two men, in which their figures reached agreement in but 12 per cent.

Position of the greater trochanter is of great importance. It is drawn upward by the iliopsoas, everted with the limb and drawn nearer to the middle line of the body and the anterior superior spine of the ilium by the adductors. To determine its position the following tests are helpful and quite accurate: Nélaton's line is one drawn from the

FIG. 417.—Method of measuring leg length from fixed bony points. Note that the legs make equal angles with the long ruler placed between them, which lies at right angles to a cross piece joining the two iliac spines.

anterior superior iliac spine to the most prominent part palpable of the ischial tuberosity. In fat subjects the latter point is rather difficult to locate, and the line is best obtained by finding this point, holding the fingers on it and extending to it a tape or string from the iliac spine. The line can be marked on the skin with ink or skin crayon and the position of the trochanter found. Normally this line strikes the trochanter just at its upper margin with the leg in the longitudinal body axis. If the bony mass of the trochanter extends above this line, shortening of the neck from fracture, or absorption change in this axis, or dislocation backward are present.

Bryant's line and iliofemoral triangle are obtained as follows: The limb is placed in a normal position if possible, the patient lying on a

flat surface. From the anterior superior iliac spine a perpendicular is dropped to this surface (Fig. 418, *a–c*). A small wooden ruler or pointer acting admirably. The long axis of the femur extended upward *b–c* strikes this line, and the distance from the top of the trochanter to the perpendicular is measured on both limbs. In fractures the affected side will be found shorter (indicated by the dotted lines), the relative displacement upward of the trochanter being indicated by the difference in the limbs.

Morris's bitrochanteric test is little used but is of value also. The observer marks the midline of the body and by holding his head directly over this measures the distance from the midline to the outer surface of each trochanter, either by tape or by a rule with a rider on each end. Shortening on the injured side is found in fractures of the neck and in hip dislocations, but the phenomenon of relaxation of the fascia lata between the ilium and trochanter is also a natural indication of this shortening and requires no attempts at measurements, as it is plainly visible to the observer. When the fracture extends

Fig. 418.—Diagram of Bryant's line and the iliofemoral triangle. The dotted line represents the displacement upward with consequent shortening of the base line (Bryant.)

into the trochanteric area and the trochanter is comminuted and flattened, it can be felt on palpation to be thickened from subsequent infiltration. This may allow a differentiation between fractures at the base of the neck and near the head where roentgenogram is not available. I believe that efforts to demonstrate a movement of the trochanter through a smaller arc or rotation of the limb where the neck is broken are valueless. No satisfactory determination can thus be made by palpation, and it is not worth the pain caused and the possibility of breaking up slight impaction in those cases in which this is needed.

A false point of motion can sometimes be felt by the fingers of the hand grasping the trochanteric area, rotation of the leg being performed with the other hand, if the line of fracture is at the base of the neck and has allowed the shaft to be completely separated.

Hennequin's sign is valuable. By digital compression below Poupart's ligament outside of the great vessels, one may elicit pain and tenderness when the neck is broken or feel a bony mass nearer the surface than on the sound side. This is caused by the rotation inward

and upward of the head fragment and the irregularity in the same direction of the broken neck.

Diagnosis.—Uncomplicated injuries to the hip region in elderly people caused by a trip or fall, in adults caused by crushings and other severe injuries incident to occupation, which give loss of function in the limb with pain, eversion, shortening, and sometimes crepitus, are not difficult to diagnose. If the solution of the continuity of the neck is complete, it should not be difficult to diagnose, but if impaction has occurred during the application of fracture force so that slight shortening is found, no crepitus, and doubtful change in the position of the trochanter, more trouble is experienced in coming to a definite conclusion. All the points of diagnosis should be borne in mind, and in a fresh case with any doubt as to the presence of fracture no chances of error should be taken, but treatment should be that of fracture until one is satisfied to the contrary. More inexcusable errors have been committed by not following this advice than by treating suspected cases expectantly as fractures. Every surgeon may recall patients with neglected fractures in this area who have come to him months after injury limping on canes or crutches, who have never had any treatment directed toward fracture and whose legs were gradually becoming shorter. If shortening after trauma is demonstrated by careful comparison when other symptoms are positive, fracture should be diagnosed, even if a normal difference in limbs is considered. Partial loss of function only is found in some cases, but as given above, cases in children and elderly people must be watched and if possible subjected to the Roentgen rays for confirmation. Severe contusions of the hip followed by loss of power and eversion of the leg are not accompanied by elevation of the trochanter or other signs of fracture, crepitus is absent, and after a day or so of complete rest in bed function usually reappears rapidly. In elderly people no chance of error should be taken by the medical attendant. If the patient is allowed to bear weight on an undiagnosed fracture subsequent complications will surely follow, greatly lessening the patient's functional use and the attendant's reputation at the same time. When the case is not seen soon after injury the history should be carefully inquired into. Evidence of the immediate position and condition of the limb as observed by both the patient and others at the time of injury, the possible existence of former fracture not recognized, chronic arthritic changes, malignant tumors must be inquired into, and careful general examination should be persisted in. Careful measurements and manipulations should follow, and then in any doubtful cases the weight of evidence should be increased by the knowledge of many overlooked cases.

Loss of function, a small amount of shortening, no crepitus, and a normal feeling trochanter would lead to a diagnosis of impacted fracture probably near the head. If shortening is great, crepitus present, and a thick painful trochanter is palpated, fracture through the base of the neck and complete separation can be expected.

Dislocation is not difficult to differentiate; the rigidity of the limb, its usual adduction and flexed position eliminate that condition. In cases of anterior dislocation with eversion of the limb the head can easily be felt under the pubic ramus; but if the head is on the dorsum of the ilium in backward dislocation the task is more difficult. In dislocation the absence of the head in the acetabulum may be felt, or the head can be made out on the ilium. Inversion in fracture is rare and may change into eversion, as explained, when the impaction or overriding are released by traction.

Prognosis.—Prognosis depends on the age, treatment, and physical condition of the patient with the concurrent shock or additional injuries. If age alone is the greatest factor, it must be analyzed into the condition of the patient's circulatory apparatus and his reaction from shock. Each case has to be judged on the physical findings of the general condition in regard to immediate danger of life from hypostatic pneumonia, shock, or other complications. Fat patients with myocardial changes, those with chronic bronchitis, alcoholics, and others with greatly weakened general resistance usually succumb within a few days, exitus taking place in a mild febrile attack with or without delirium. In others of good habits and fair condition, death in four to six weeks is frequent, generally with an afebrile termination, gradual loss of strength, and pulmonary edema. Ashhurst and Newell[1] analyzed 58 cases with a mortality of 29.5 per cent., the end-results giving 62 per cent. useful limbs. Walker gave results in 112 cases treated by the abduction method, 16 per cent. dying during treatment with end-results of 42 per cent. useful limbs. Ruth[2] claims 100 per cent. bony unions through the Maxwell treatment with far less chance of the ordinary lung complications, because the patient can be put in a sitting posture and apposition of the fragments maintained.

While the immediate mortality is high up to the first six or eight weeks, if the condition of cure progresses to a stage to allow the patient to be up and about on crutches or in a splint, more bony unions are obtained than was formerly expected, especially under the modern treatment, both operative and simple. Cotton[3] considers that an overregard for the patient's health may lead to an underregard of treatment, and that most cases can be treated surgically and yet made comfortable. Results with shortening, eversion of the leg, and a limp are the rule. Restriction of the hip motion is inconstant, depending on the degree of abduction with the change in the axis of the shaft and the periarticular changes which are caused by faulty reposition and immobilization, or the result of the individual's tendency. These people can get about quite comfortably, employing a cane and find little restriction to their activities already curtailed by age. They tire quickly, but soon learn to gauge their physical limit and are fairly content. Some hips remain constantly painful

[1] Ann. of Surg., 1908, xlviii, 748.
[2] Loc. cit.
[3] Loc. cit.

and give much arthritic pain even when the result is fair. Walker's statistics give 18 deaths out of 112 cases, 32 patients not found, 30 unable to work because of persistent pain and restricted movement at the hip, usually because of shortening and abduction; 22 showed improvement and fair satisfaction.

Fibrous union or non-union may be accompanied by good function and no pain. Murphy[1] says that after fracture both fragments readily undergo absorption on account of the peculiar blood supply of the bone and the erosion of one fragment against the other, and that additional reasons for poor union can be found in the fact that this fracture is common in the aged, who have diminished osteogenesis. The bone after union under faulty conditions and position becomes subject to a severe strain at an oblique angle to its long axis, because though we can control the position of the distal fragment to a certain extent, we cannot control the head fragment, and approximation is very difficult.

Conant[2] cites 7 cases in which the results were bad in 2 and fatal in 1. He believes conservative treatment should be adopted for nine months before operation is considered and that close attention to the condition of the spica and its firmness in cases treated with immobilization in plaster will improve results. Operative results of fixation and removal of the head are given under Treatment.

Treatment.—(1) Immediate treatment concerns itself with complications and other injuries, shock, or transportation to a place of permanent treatment. Fixing the leg to its fellow, after carefully straightening the eversion by bringing the foot into line, can be done by bandages or blanket splints covering both limbs. A Liston splint or any long padded board which will extend from axilla to heel is sufficient to offer support by firm bandaging. In the aged, or when impaction is determined, no manipulation should be attempted until the findings have been carefully noted and analyzed.

(2) Permanent non-operative treatment is usually directed along the following lines: (*a*) When age or other conditions threatening life are present, the first care is to preserve it. Prolonged immobilization or even a recumbent position may be contra-indicated, so that stimulants, sedatives and support in a reclining position are needed. The large ambulatory splints, either with felt pads or pneumatic cushions are useful in cases where the patient is able to carry them on crutches or with support, but, usually, feeble patients who really demand the ambulatory care, are unable to sustain the weight and restriction of these devices. These are put to bed well bolstered up, and sand-bags, rolls of blanket, and other supports are used to hold the limb in comfortable position. If impaction in these cases is present, it should be preserved. A little stronger class of patients will obtain this treatment and in addition can tolerate a Buck's extension and slight elevation of the foot of the bed to act as a counter-pull. Main-

[1] Ann. of Surg., 1903, p. 593.
[2] New York State Jour. Med., xiv, No. 3, p. 150.

tenance of personal cleanliness without much pain, the use of pads beneath the buttocks to avoid decubitus and a reasonable degree of comfort and control of the wabbly limb are supplied by simple support without much distress to the patient. Satisfactory functional results follow this treatment in perhaps 30 per cent. of cases, but the mortality is high, and shortening always exists.

(*b*) Continuous extension. If we lay aside this above-mentioned class which represents really not a large percentage of the whole, the majority are to be cared for to obtain bony union if possible, and a minimum of shortening and displacement, for these two factors are the basis for future happy function. Some form of extension is indicated; on that point all agree. Its method of application and other expedients needed to have and hold apposition of fragments depend on the site of fracture. Buck's extension is excellent treatment if applied properly. This extension applied with well-fitting zinc oxide plaster on a carefully shaved limb is in much general use. Counter-extension should be provided for by the raising of the foot of the bed six to ten inches on blocks and the attachment by the pulley rope of a weight of ten to thirty pounds. The weight used has not been heavy enough in the past, and it should be increased so that a gradual, steady, and sure lengthening of the limb takes place until the trochanter is brought down to its proper level. It is impossible to apply extension and hold the leg in abduction at the same time unless accessory splints are used because the patient shifts his position by tilting the pelvis. A perineal band for counter-extension is also advisable. But after application, if the weight is kept pulling and the spreader or the opposite foot do not get in contact with the end of the bed, the pelvis tilts a little toward the injured side and abduction in a measure is obtained. At least the adductor muscles are stretched and tightened and they act as a means of holding the fractured ends in contact. If control skiagrams are made after the treatment it can be ascertained that the neck lengthens slightly and assumes a better axis. Continuous extension by the Buck arrangement can be combined with the Hodgen splint, which is a gutter splint, suspended by wire or rope, raising the whole thigh and leg from the bed with the knee slightly flexed. By the fastening of the foot to the end of the splint some degree of extension can be obtained by its own weight, or the Buck's extension may be added with the leg in this position.

The long rigid Liston splint has little place in scientific treatment of fractures of the femoral cervix. It cannot, even with padding, be made to conform well to the curving chest wall, as it must do if it is to hold firmly; it allows for no extension if the leg is held straight by being strapped or bandaged to it, and it ties the patient down completely to a flat position. As a temporary measure it is excellent; as scientific treatment it should be discarded.

Anesthesia is rarely needed for correction of position to a simple upright position of the foot and a straight limb, but if mechanical extension is first to be applied by either human or instrumental agency,

anesthesia is indicated to relax muscles in order that impaction may be broken and an efficient reduction of fragments be secured. Ewald[1] advises disimpaction in all cases where prolonged after-treatment is not likely to be followed by pulmonary complications. Stimson[2] considers reduction of displacement essential to proper repair, but believes it is disadvantageous in fractures at the base of the neck with crushing into the trochanters, because an hiatus would exist between the fragments. This is particularly true when the posterior surface of the neck is more crushed or telescoped than the anterior and disimpaction might so separate the surfaces that no manipulation would ever bring them together. Treatment by breaking up of impaction followed by abduction is also advocated and was practised by Senn many years ago. He broke this up and then swung the leg in marked abduction, encasing both thighs and trunk in a plaster-of-Paris body cast. Embedded in this cast was a thumb-screw with a flat end which pressed on a pad placed over the trochanter, its support being assured by enclosure in the cast. By turning this up he could secure increased pressure later when the cast dried and loosened, or the parts within became shrunken, so that constant pressure was maintained against the trochanter to hold the neck against the broken-off head. Whitman and Walker also advocate the abduction treatment but without the forced pressure on the trochanter. This treatment aims to hold the fragments in contact and to give a union with the normal angulation of the long axis of the neck restored. When removed from the splint and brought down to a straight position the neck axis, being normal, overcomes a tendency to shortening. Although he likes the abduction method, Cotton[3] criticizes it, inasmuch as it is difficult to avoid letting the fragments slip past each other in the manipulation. This treatment requires the heavy body cast and is open to the objection of its weight and irksomeness and the helplessness of the patient, and though the results obtained are possibly better than those with a Liston splint, with or without Buck's extension, or a simple Buck's extension, the confinement in the cast must be considered. Casts also will break or crack, the soft parts within will shrink, and looseness makes a reapplication necessary. This is tiresome, expensive, and may demand anesthesia. A single spica encasement of the thigh and body is also used but allows of no abduction to overcome angularity of the neck and no traction to provide for extension. To maintain abduction in one or both legs it is necessary to enclose one leg and the abdomen completely to fix the pelvic bones and the opposite thigh to the knee. If this is not done the lumbosacral spine curves around and no abduction is possible (Fig. 419).

Two better and lighter methods of maintaining abduction and extension are found (Figs. 421, 422, and 423). The Thomas splint

[1] Wien. klin. Rundschau., September 19, 1909, p. 597.
[2] Fractures and Dislocations, 1913.
[3] Am. Jour. Orthop. Surg., viii, No. 4.

from the lower dorsal region to the heel is used on one or both legs. This splint is light, and by means of a perineal band of leather which is tightened to the rigid frame, extension is applied by Buck's, which can be fastened to a ratchet at the foot. *Any degree* of extension on

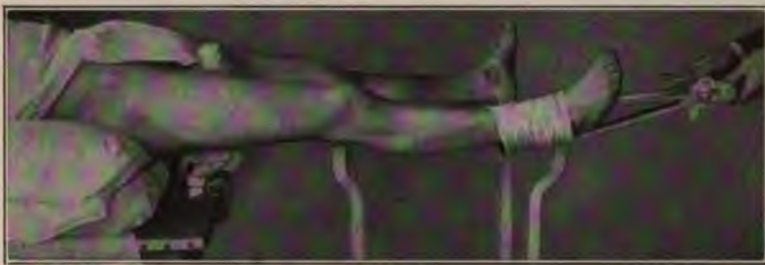


Fig. 419.—A portable apparatus for mechanical extension of the leg. Satisfactory traction can be obtained by turning up the ratchet at an abduction angle which is held while a body plaster encasement is applied.

the leg can be exerted. Abduction is also provided for. Jones, of Liverpool, uses this exclusively for fracture and operated cases in place of plaster of Paris, which I have seen him use only in the congenital dislocation of the femur. It is a most serviceable splint, can

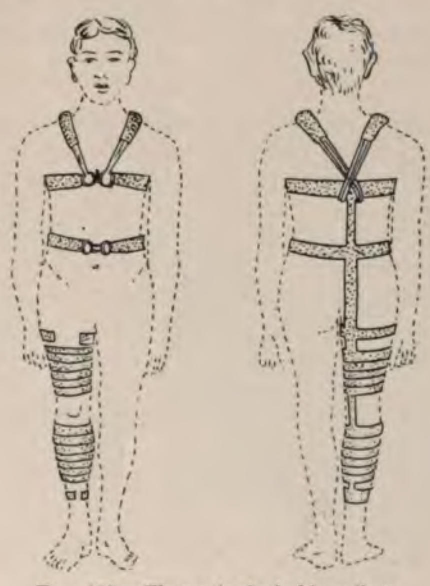


Fig. 420.—Thomas's single hip splints.

be made cheaply, and can be used many times over. It is surprising it is so seldom seen in America.

The second splint, one which we use continuously at the County Hospital, Chicago, is the Rainey wooden splint (for which see Fig.

424). On this the patient rides comfortably and any desired degree of abduction of one or both limbs can be obtained. Simply through

FIG. 421

FIG. 422

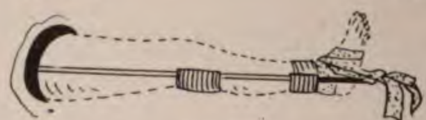


FIG. 423

FIG. 421.—Thomas's double hip splint for maintaining abduction and extension. Any angle can be obtained, and when used on a child, the child and apparatus can be picked up and moved at will. The Figs. 422 and 423 represent the Thomas hip splint for extension on the leg and a walking caliper with a heavy perineal pad.

being bandaged to the splint the patient cannot turn over to one side or the other (Fig. 425). The abduction is fortified by extension on the injured side by means of a Buck's extension with the required

FIG. 424.—The Rainey wooden splint for immobilizing the hips in any degree of abduction. Both side pieces held by metal clamps move in the slots of the cross pieces.

weight from ten to thirty pounds, and the foot and leg can be bound into inversion without destroying the traction. Especially valuable

is this in operative cases, which may be dressed without disturbing the apparatus at all. Our routine non-operative treatment in cases which tolerate extension consists in this splint with suitable extension to overcome shortening and the proper angle of abduction and inversion for five or six weeks, followed after that time, if bony union

Fig. 425.—Patient in bed on a Rainey splint. Note the fracture bed formed by the supporting board across the middle.

is satisfactorily inaugurated, by a light plaster-of-Paris spica around abdomen and one leg to hold the position gained and protect the leg from possible refracture, the patient being allowed to get up on crutches an hour twice a day. After ten to fourteen weeks the plaster is removed and with a lift on the side of the uninjured foot so that no weight

Fig. 426.—Suspension method for treating fractures of the femur in children. (Richter.)

can be borne on the injured hip. Crutches are furnished and no weight is allowed for from five to seven months.

The Philips-Maxwell[1] method of extension and counter extension (Fig. 426) as described by Ruth,[2] is called by him the anatomical method.

[1] Philips, Am. Jour. Med. Sci., lviii, 398. [2] Loc. cit.

He reports over 100 cases so treated and claims bony union in all. Arguments advanced in its favor are as follows:

(1) It overcomes displacing influence of muscular action.

(2) It keeps all soft tissue from interference with union.

(3) It uses the intact portion of the capsular ligament to maintain alignment.

(4) It causes no pain.

(5) It is applicable to all cases.

This treatment is briefly:

(1) The thigh is flexed at right angles to the trunk that the line of action of the psoas and iliacus may be brought above and away from contact with the anterior surface of the joint.

(2) Outward pull on the upper end of the lower fragment is made by an assistant that the trochanter major may be brought out as prominently on the injured as on the uninjured side, while traction is made on the limb until all displacement is overcome.

(3) The lateral pull on the upper end of the lower fragment is adjusted and steadied, and by Buck's extension and counter-extension to the limb in line with the trunk, normal length is maintained.

(4) Adjustment of traction by pulleys and weights is made both in line of the body and laterally so that there shall be no tendency to shortening, eversion of the foot, flattening of the hip, or dropping of the greater trochanter below its normal level.

The foot of the bed and the side corresponding to the injury, should be raised to counteract the body weight and to overcome the tendency of the patient to be drawn toward the lateral point of traction. As the upper fragment is passive, this adjustment continues whether the patient is flat or sitting up. This lateral pull is obtained by a weight adjusted on the side of the bed at the level of the anterior superior spine about ten inches above the mattress, connecting with a band of adhesive plaster four inches wide passed around the thigh high up and held open by a wooden spreader. To avoid pressure of the veins of the thigh a thick piece of saddler's felt is applied to the inner surface beneath the adhesive. The spreader, in addition to leading to avoidance of venous pressure, also insures better inward rotation of the limb. This lateral traction rolls the femoral shaft in, pulls in the longitudinal axis of the neck, holds the fragments in contact, and puts the capsule on the stretch.

Dyas[1] has ingeniously modified this by placing a piece of 8 x 4 scantling parallel to the side of the bed about two and a half feet above it, fastened at both the head and foot, and at a point opposite the anterior superior iliac spine by nailing another 2 x 4 piece at right angles to the horizontal piece. A fracture bed is made, and the lower end of the perpendicular scantling is nailed to one of the boards to afford a rigid support for the pulley and lateral weight. This side bar can also be used by the patient to shift his position

[1] Railway Surg. Jour., April, 1914.

in bed and raise himself on to the bed pan. The lateral traction weight is about two-thirds as much as the longitudinal, *i. e.*, from ten to sixteen pounds. The weights are greatest when the treatment is started, but as the muscles relax they are reduced. Every third day the knee is flexed with an assistant making traction in place of the weight removed.

Cotton[1] believes that all Ruth's cases were fractures at the base of the neck and that this treatment is decidedly non-anatomical for those near the head (intracapsular), as the lateral traction tends to separate the surfaces. If a true neck fracture has no real impaction or it has given way, the position is to be corrected, not through breaking up the impaction loosely, but through remodeling it, this being accomplished by the abducted position and recourse to malleting.

Operative Treatment.—Open operation is reserved for certain cases subject to the general conditions and restrictions expressed in the chapter on Operative Treatment, but broadly speaking to those cases in which the closed method fails. It should not increase immediate mortality, and it should prevent the unfavorable results of conservative treatment, or the functional results of conservative treatment must be shown to be intolerable before all cases are operated on. Absence of union is difficult to determine before open operation; the following facts should be determined as an aid to belief:

(1) Ability to push the trochanter upward.

(2) Rotation of the trochanter in an arc smaller than that of the uninjured side (doubtful).

(3) The relative position of the trochanter shown by two roentgenograms, one taken lying at ease, the other with force pushing upward on femur.

Indications for operative treatment are:

(1) Ununited loose fibrous union of at least ten weeks duration under conservative treatment, with loss of function, in those able to withstand operation.

(2) Unrecognized and untreated cases with disability, cases which have been called sprains or dislocations.

(3) Marked angular deformity and shortening in children and adolescents, conditions which lead to coxa vara and further shortening.

(4) Fracture resulting in shortening and deformity in vigorous adults on whom extension has little effect and cannot be maintained.

(5) Cervical fractures complicated by dislocation of whole or part of the head.

Methods.—(1) Artificial impaction as proposed by Cotton.[2] This, while really not an open method, involves anesthesia in nearly every case, and is put here for convenience. This method is used to "assist nature," and is based on the fact that the fracture leaves two surfaces of cancellous bone with a cortical shell which can be brought into approximation and then be hammered together by force applied on

[1] Boston Med. and Surg. Jour., clxx, 718.
[2] Am. Jour. Orthop. Surg., viii, No. 4.

the trochanter. Under light anesthesia the leg is drawn down and crepitus obtained between the fragments; then a felt pad is placed over the trochanter on the injured side, counter-pressure is made on the opposite side of the pelvis, and half-dozen blows with a heavy wooden mallet are given over the trochanter in the direction of the neck axis. The leg is then tested to see if its tendency to shortening or eversion has been lost, or if the shaft rotates on the neck axis. If the impaction holds, the leg is put in a long side splint and traction is discontinued. This tries to do at one sitting what the Senn method hoped to accomplish by constant pressure. The original article cited two cases, the first in a man, sixty years old, who after a year had one-half to three-fourths inch shortening with slight eversion, but who could not raise his heel from the bed with leg in extension. The second was in a man, forty-eight years old, who obtained bony union with no shortening but with some rotation outward. The question arises in deeply impacted cases with shortening whether they could be loosely broken up and reimpacted by this method.

(2) Open operation with simple replacement after freshening the fragments. Whitman[1] reports an unrecognized case of neck fracture in which there was a fraction of an inch shortening with outward rotation and muscular fixation. This he opened, and found the head lying separately and behind the neck, but by rotating the limb inward, the fragments being held separated by a chisel, he was able to restore it to a normal position. Dowd (same page) reports a similar case in a ten year old girl treated three years before, in whom there existed after that time no shortening, but the roentgenogram showed depression deformity of the femoral neck, a fact from which he concluded that this femur had apparently grown more than the other. Nothing was said as to the possibility of pelvic tipping. Albee also mentions such a case.

(3) Open operation for nailing on the head with nails, or bone, or ivory pegs. Many instances of these operations are now in the literature, and the relative value of just what material is to be used depends on the operator's choice and confidence in his asepsis. Originally this was Nicolayson's method, in which, without opening the site of fracture, he drove a nail through the trochanter into the head and on into the acetabulum to insure immobility. Various refinements have followed, directed toward assurance of alignment of the two fragments by exposure through the opened capsule, and there have been variations in the character of and method of insertion of the fixing agent. Cotton[2] considers the nail a temporary fixation; so he leaves it projecting beyond the skin surface, removing it after three to six weeks. Dawbarn[3] first pulls down the trochanter by a few days' Buck's extension; then, under local anesthesia of 0.5 per cent. cocaine in the skin and 0.2 to 0.1 per cent. in the deeper tissues, he incises with midpoint three inches below top of great trochanter. He drills

[1] Ann. of Surg., xlvii.
[2] Loc. cit.
[3] Ann. of Surg., xlvii, 120.

the femur through the cortex and then introduces a long steel trocar at an angle of 125 to 130 degrees slightly forward toward the head. Into this he passes a three-inch nail, the head of which he files off and drives on into the bone substance for an inch to become absorbed or encysted. In addition he injects arcund the nail tract a boiled solution of one-half each pure glycerin and glycerit tannine (U. S. P.) to promote callus formation.

Technic of Open Operation.—Approach to the hip-joint is possible through three incisions:

(1) Anterior angular between the tensor vaginæ femoris and the sartorius. This does not demand the cutting of any muscles, as there are none in front of the femoral neck except the iliacus, which is attached below to the lesser trochanter. Division of the fascia and deep separation brings the operator at once to the femoral neck but does not allow much room.

(2) Posterior or Kocher incision behind the trochanter, which involves cutting the glutei muscles and the pyriformis.

(3) Lateral U-shaped incision about the trochanter. After a flap of skin, fascia, and fat is reflected the greater trochanter with its attached muscles is removed by a Gigli saw and turned upward.[1] This exposes the neck of the femur and the joint capsule. If the joint is not open the surgeon incises it, and by abducting and rotating the limb outward brings the fragments into view. The operator proceeds to examine the line of fracture, especially as to (*a*) viability of fragments, as determined by their color or by the scraping of the bone ends to obtain oozing of blood; (*b*) pseudarthrosis, or pieces of capsule between· (*c*) amount of bone absorption of the neck and feasibility of approximating the fragments. If the head is viable, or is to be fastened on as a transplant, necrotic but aseptic, the fractured edges are radically freshened and a long nail is driven through the trochanter into the head with the leg held in abduction and mechanical extension. The joint capsule may then be closed by catgut and the trochanter attached to the femur again by a small nail, and the deep fascia and skin closed. If the head has been completely absorbed, the muscles attached to the trochanter are relieved of their insertion in accordance with Murphy's[2] method, and four-fifths of the trochanter is cut off, reattached by nail to the head end of the neck, and placed in the cleaned-out acetabulum. This method is applicable to fracture dislocations with the head out of the acetabulum and in an unusable condition. Fragments of joint capsule are trimmed off and removed from a position between fragments, and the limb is put up in abduction for ten to twelve weeks on a Rainey splint; not be be used for six months.

Fixation by pegs of autogenous bone, or by ivory, has been done with success. If there is not much absorption of the neck, and there is no objection to taking the tibial splint, this is the operation of

[1] Murphy's Clinics, ii, 425. [2] Ibid., p. 16.

choice, because no foreign body is left behind (Fig. 427). The trochanter can be sawed off or not—better not—and a suitable hole opened on the femur, a small tunnel dug down into the neck with a curette or reamer and the bone splint driven home as if it were a nail, the leg in abduction. Very careful subsequent handling is necessary to avoid breaking the peg. Immobilization should be about three months in abduction. Davison[1] and others have reported operations of this character.

Suturing of the periosteum is not a useful procedure. König, quoted by Stimson,[2] obtained one good result in five cases. If exposure sufficient to allow periosteal suture is made and this difficult task performed, it would be wiser to insure bony approximation by one of the fixation methods. Excision of the head with placing of the upper

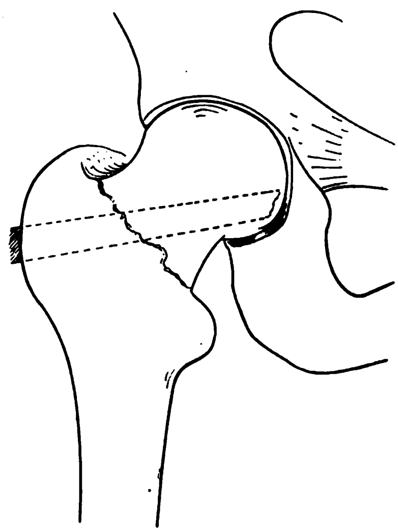


FIG. 427.—Fracture of the femur; operative repair by bone peg of fracture at the base of the neck.

end of the femoral neck in the acetabulum is used in some cases, but many viable heads are removed, which if attached would become firmly united and give better function. To remove the head one has to free it from adhesions, cut the ligamentum teres, and then pry it out of the acetabulum, the cartilage being curetted out with a sharp spoon. The trochanter can be attached to the neck as a new head. When the fracture site is exposed, the head fragment is shown to have insufficient circulation by its yellowish color and smooth areas of friction on the neck. The centre may be deep yellow, and when curretted shows no oozing from the dry and friable bone, but around the edges of the torn capsular reflection some blue or red patches

[1] Surg., Gynec. and Obst., June, 1914, p. 750; Jour. Am. Med. Assn., lxii, 1551.
[2] Fractures and Dislocations, 1912, p. 353.

may persist, which indicate a slight blood supply. Generally the shaft fragment is a marked contrast in color and covering, apparently surrounded with well-nourished, bony granulations which bleed easily. Flint[1] says: "Excision (of the head) is to be preferred, because circulation has been demonstrated to be insufficient to favor union even after adequate approximation."

In the aged when the fracture is near the head it is best to excise it within a few days if the general health permits. Patients will do better from early operation either with an ankylosed hip or a loose joint than with a long conservative treatment only to be subjected finally to open operation when unfit for it. Further indication for removal of the head is found in those instances of seeming bony union obtained by any means which in a few months after use show an abnormal joint accompanied by pain and disability or in which at the time of operation, fixation of the head is precluded on account of:

(*a*) Extensive crushing or very jagged break of the neck.

(*b*) Presence of cystic spaces containing reddish-brown material following absorption of the cancellous bone from nutritive disturbance in those, either old or young, in whom a false joint has existed from six months to a year. These cases always permit upward displacement and rotation of the shaft with absorption of the neck. The trochanter rests on the acetabulum and no fixation is of value, because the head is firmly fixed in the acetabulum and its cartilage is destroyed. As mentioned above, if the displacement were corrected to a normal position, there would exist an hiatus between the neck and head, especially on the posterior surface. Flint[2] believes the trochanter should be tilted up by a linear osteotomy to allow the neck to fit into the acetabulum and the anterior edge of the acetabular margins cut away to avoid outward rotation of shaft.

In fracture dislocations when the acetabulum has become filled with fibrous tissues these are removed before the reattached head is replaced, and the turned-in part of the capsule is attached to the margin of the acetabulum to prevent ankylosis.[3]

In operative cases which are fixed by mechanical internal splints I prefer to make roentgenograms of both hips from the same angle to be able to make the fixation at the same or an exaggerated angle on the injured side. These pictures assist in determining the direction of the nail and the degree of abduction needed. Gerster[4] states that intracapsular fractures in the young show best results when spiked.

Instances in which capsular interposition obstructs union would never give firm attachment by any other than operative treatment, and if no union is started after eight to ten weeks in cases amenable to operation, they should receive the open treatment. Murphy[5] calls renewed attention to this and the fact that there are three important elements in femoral neck fracture.

[1] Ann. of Surg., xlviii, 729.
[2] Loc. cit.
[3] Murphy's Clinics, ii, 425.
[4] Am. Jour. Med. Sci., August, 1913.
[5] Clinics, i, 165.

(1) A tendency to shortening (which must be overcome by extension).

(2) A rotation of the fragments.

(3) A force to make continuous apposition of the fractured surfaces, which can only be obtained by abduction of both limbs.

In nailing the head on the neck he advises using two nails inserted at different angles to avoid rotation of the head fragments (see Fig. 428).

Final Results after Operation.—(1) If fractures of the neck of the femur are successfully nailed or pegged with bony union there is a slight shortening and a lameness but a very useful and painless limb.

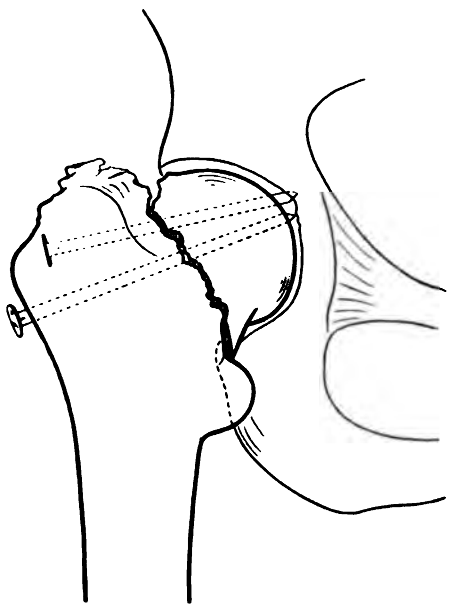


FIG. 428.—Fracture of the neck nailed while the leg was under mechanical extension. The only fault in the operation lay in the projection of the nail points into the acetabular wall, leading to their removal, although aseptic nine months later. Some shortening of the leg followed, showing an incomplete bony union.

(2) If operation is less satisfactory, union may be present, but there is also shortening, abduction, and rotation outward, so that function is impaired and a cane or crutch is needed (Fig. 429).

(3) If a fibrous union follows and the operation has been a failure, the hip assumes a position such as found in non-union, accompanied by discomfort, pain, and shortening until the trochanter is finally displaced well upward on the ilium, held in check only by the Y-ligament.

When the head is excised, effort should be made to obtain bony union to the pelvis, a condition giving shortening and lameness which are compensated for by the tip of the pelvis and the spinal curvature in the lumbar region.

Fracture Through the Great Trochanter.—Kocher's Pertrochanteric Fracture.—This fracture, when clear dry roentgenograms of hip fractures are studied, is of more common occurrence than is usually believed. The head, neck, and greater trochanter form an upper fragment which remains in a normal position. The plane of fracture starts from the trochanter a short distance below its tip and passes obliquely downward and forward to the base of the neck, leaving the lesser trochanter attached to the shaft. This line may extend in a direct oblique plane from the front to the back of the bone, or be oblique in its anteroposterior plane, so that the opening of the frac-

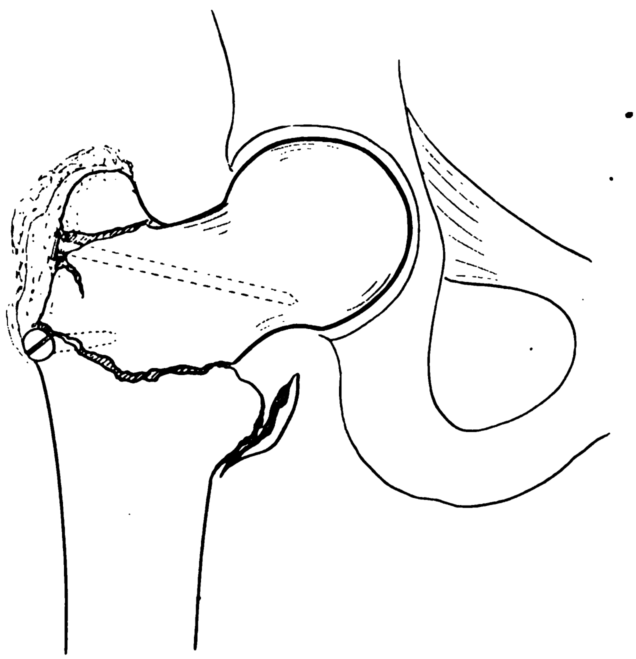


Fig. 429.—Fracture at the base of the neck through the trochanter nailed and screwed on. A good callus is evident. These are favorable cases for operative fixation.

ture is higher in front than it is on the rear of the bone. The findings in these cases which I have studied divide themselves into three classes:

(1) The upper fragment of neck and greater trochanter may be jammed down into the oblique surface of the upper end of the shaft in an impaction with the strong calcar femorale, tending to penetrate into the softer tissues of the lower fragment. When we consider the driven-in appearance of the calcar femorale we cannot but conclude that the condition has been brought about by severe violence applied to the trochanter in general direction of the neck axis followed by a

yielding in this oblique fashion of the trochanteric area and an immediate adduction of the limb and lower fragment.

(2) The upper fragment may be slightly separated from the shaft with a similar line of fracture, force having been received in the same manner as in (1) followed by immediate abduction of the limb and lower fragment.

(3) More marked examples of type 2 with separation at the lower angle of the fracture possibly involving a splitting off of the lesser trochanter and a slight impaction of the upper end of the lower fragment into the neck. These are very severe breaks occurring in young adults due to extreme violence and accompanied by shortening, abduction, and eversion of the leg. The separation is not great and the pseudo-impaction may not allow crepitus. The trochanter continues to move with the shaft on gentle manipulation, but shortening is marked and the angulation forward of the base of the neck may be demonstrated, or at least the point of tenderness be definitely located by pressure. In complete separation the characteristic finding is absence of the movement of the greater trochanter with the shaft. Secondary cracks or splits may radiate into the femoral neck, the trochanter, or run down into the upper end of the shaft. One case here given as an illustration was complicated by a fissure running down the shaft in such a manner as completely to dislodge a portion of its external surface. Extension treatment made no gain on the shortening, as the shaft fragment would not remain out in contact with the broken-off trochanteric area and abduction merely made this displacement worse. Open treatment was decided upon, and when the site was exposed the isolated fragment was found loose with all periosteal attachment destroyed. It was accordingly lifted out of the wound, split into two pieces by a chisel, and one piece used as an intramedullary splint. The upper end of this was driven well into the cancellous portion of the trochanteric area, as there is no medullary canal there, while the leg was adducted and flexed and the lower end slipped into the open medulla of the shaft, the procedure permitting a perfect replacement of the fragments with use of a portion of the fracture for repair. Subsequent handling was very cautious until the cast was applied, and a skiagram a week later showed perfect reposition. Inside of eleven days, however, the cast broke across the groin, the patient became unruly, and a slipping back into the original displacement took place in part. Though the final anatomical result was not perfect, the shortening did not exceed three-eighths of an inch and the function was extremely satisfactory. (See roentgenogram drawings and photographs, Figs. 453–456.) With little separation, the treatment is extension with the thigh either in slight flexion, in abduction, or in a straight line, according to the type of fracture.

In instances of marked displacement or complicating fracture planes the subject of open operation will be carefully considered. These breaks cannot be plated, there is nothing above the line of fracture to which the plate can be attached, and the only thing which will

hold, will be nails or screws, or wire, or such device as used in the case cited. Immobilization should be thorough and long-continued, at least three months, and great care should be used in allowing weight bearing, as the soft callus might give and permit much subsequent shortening. Excess callus, causing a lumpy mass, is a frequent result in these hips.

Fracture of the Great Trochanter.—This fracture is infrequent and is caused either by direct violence received on the trochanter, or by muscular action accompanied by torsion of the whole limb inward. In the latter instance the plane of separation generally follows the epiphysis and the injury is in adolescents. The trochanter arises from a separate ossification centre and is really a point of attachment

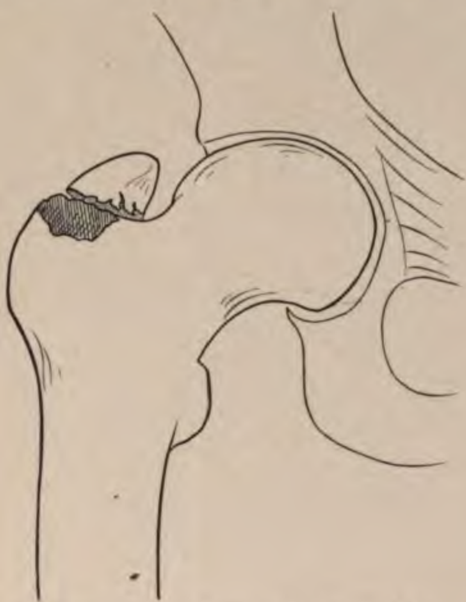


Fig. 430.—Fracture of the greater trochanter, the loosened fragment pulled upward and backward by muscular attachment.

for the rotator muscles (Fig. 430). These tend to draw the detached trochanter backward and upward, but as it is rare for the periosteum to be torn for its full circumference, the separation is not, as a rule, great. In children the trochanter is found approximated to the pelvis and pulled backward so that satisfactory external rotation and abduction may be limited if it is allowed to heal in this position. Slight muscular strain or sudden overadduction and rotation inward may cause this trochanter to separate along its epiphyseal line in those children in whom a low-grade epiphysitis is present. The inflammatory reaction causes bone absorption and weakens the physical resistance of the epiphyseal area, and powerful muscular pull easily produces a separation. This allows drainage of the inflammatory products into the

surrounding tissues and causes hemorrhage and infiltration of fresh leukocytes with a curative result. Sprain fractures with pulling out of the periosteal insertion are clearly demonstrated by roentgenogram and demand diagnosis to be given treatment of rest until healed.

Symptoms and Signs.—Symptoms and signs are pain on pressure over the trochanter, a little swelling and looseness of the fragment when the limb is rotated and separation is complete enough. Forced inward rotation of the thigh is painful and voluntary outward rotation is limited. In most instances locomotion is possible (Fig. 431).

Fig. 431.—Incomplete fracture of the greater trochanter. The planes of separation are caused by the traction of the pulled-out muscles and direct violence.

Treatment.—Treatment is by immobilization with a plaster dressing, the limb being abducted and rotated outward to favor apposition of the fragments. If the disability is great or if the separation at the epiphysis is marked and fear of lessened future function is held, the detached trochanter can be easily nailed on to the shaft through a very small skin incision, the limb being held in abduction and outward rotation during the operation. Subsequent immobilization need not be longer than four weeks.

Fracture of the Lesser Trochanter.—Stimson states that 12 cases or specimens of this injury have been reported, 9 observed since 1908 with the diagnostic help of roentgenograms. Most cases are found

in young people, generally boys, the fracture occurring during the course of games or running when a sudden stop is made to avoid either falling or collision, or being caught. The psoas muscle is inserted into this trochanter and its powerful contraction causes a pulling-off of the bone fragment. In adults the fracture is caused by muscular action from severe strain or by a sudden misstep followed by a reflex contraction of this muscle. One case seen by the author in an adult man was caused by violent muscular exertion, in wrestling, with the leg pinioned by the opponent (Figs. 432, 433, and 434). In children loss of function may not be total, but nearly all the recorded cases in recent literature state that the children were conscious of a definite

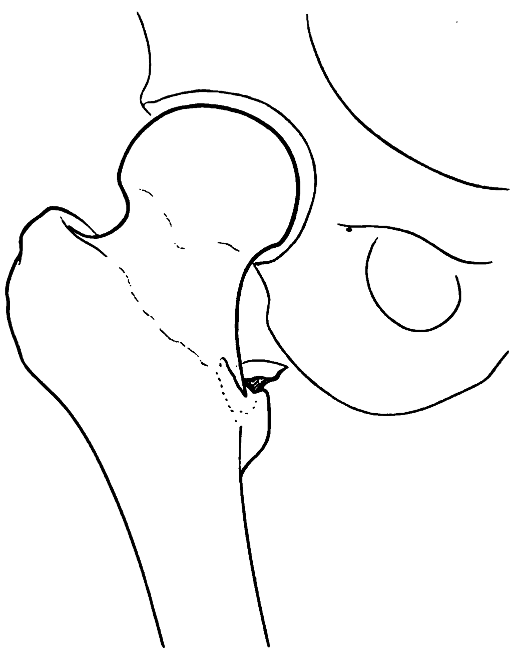


Fig. 432.—Fracture of the lesser trochanter caused by muscular action.

time in their running when the accident occurred, and some were conscious of a sudden snap in the thigh accompanied by pain. Few instances of fall on account of the fracture are recorded, and many were able to walk, sometimes to their homes.

The common findings are pain on walking, pain or pressure over the lesser trochanter, free passive movement of hip in all directions with pain on complete extension. This pain may be cramp-like on standing and is relieved by the patient assuming a sitting posture. There is lack of active power to flex the thigh in most cases, but in some cases this power is present. The psoas muscle is inserted in the top of the lesser trochanter, and in case of avulsion of the bone its contractive power would be completely lost, but the iliacus, which is

bound together with the psoas, takes a broader insertion, stretching out below the trochanter with some fibers inserted into the upper part of the linea pectinea, so that if the psoas has completely lost

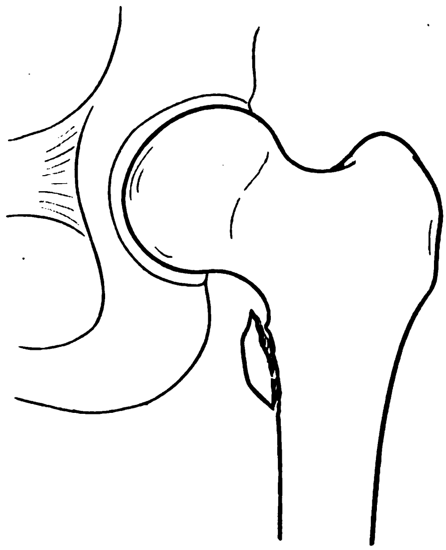


FIG. 433.—Complete isolated separation of the lesser trochanter.

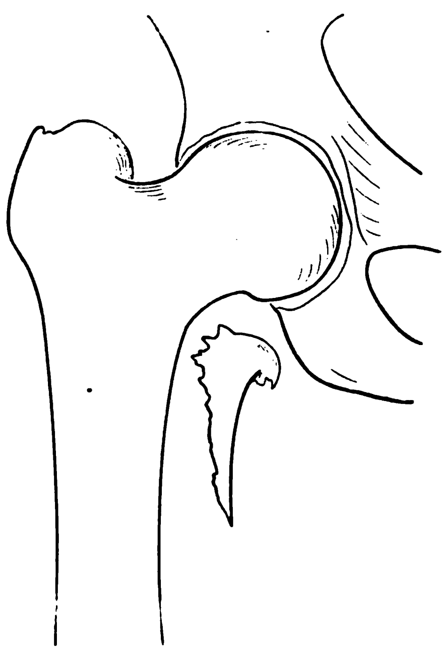


FIG. 434.—Complete separation of the lesser trochanter with a wide separation of the fragment.

power these fibers of the iliacus may still be intact and produce voluntary flexion of the thigh.

Localized swelling is not marked, but ecchymotic markings are apt to appear in a few days. In adults the limb is everted and looks like a fracture of the femoral neck, although shortening and other prominent findings are absent.

Two additional signs are Vorshütz's referred pain to the knee region and Ludloffsche's sign, which consists in an inability to cross the

FIG. 435.—Comminuted spiral fracture just below the trochanter. Note the overriding and separation of the lesser trochanter.

legs, *i. e.*, to throw the injured knee over the sound one. This latter sign also will fail if the iliacus insertion remains valid. Roentgenogram is necessary for positive diagnosis.

Treatment.—Treatment consists in the placing of the patient in a sitting position in bed, the limb being supported in an upright or slightly inverted position by sandbags. Walbaum[1] reports two

[1] Deutsch. Ztschr. f. Chir., cxxviii, 139.

cases in children, both of whom recovered promptly with this treatment, one being able to walk at once after ten days rest in this position, the other in twenty-three days with no subsequent trouble.[1]

Fractures of the Shaft of the Femur.—The shaft is the seat of all types of fracture and is frequently complicated by fractures through the greater trochanter and neck, through the lesser trochanter and

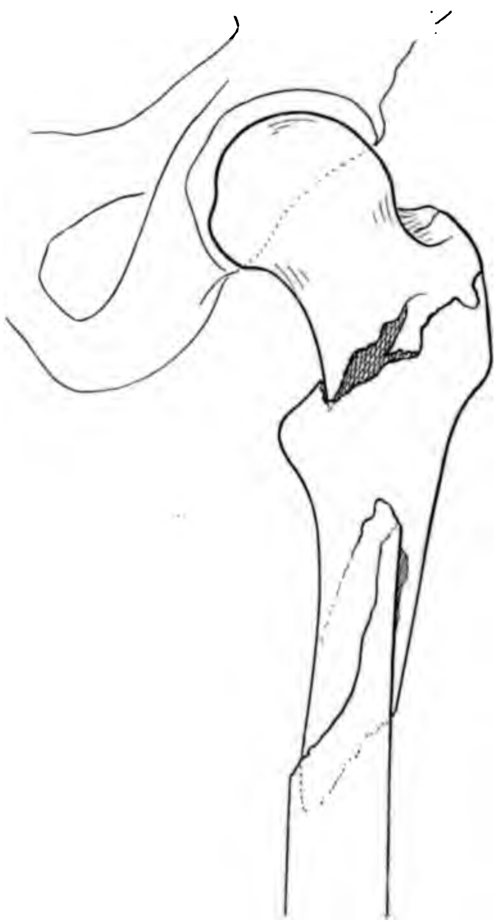


Fig. 436.—Oblique fracture of the femoral shaft complicated by an intertrochanteric fracture. The intermediate fragment is not greatly displaced.

through the lower end of the bone (Figs. 435, 436, and 437). The bone can suffer multiple fracture, spiral breaks may extend from one end to the other, and comminutions of all degrees are found.

Causes.—The causes of fracture of the shaft are direct and indirect violence and muscular action as detailed in the chapter on Etiology.

[1] Deutsch. Ztschr. f. Chir., Bd. cxvii, S. 243; Deutsch. Ztschr. f. Chir., Bd. cxix, S. 557.

Pathology.—The type of fracture depends on the part of the shaft involved and is influenced by the normal curve of the bone, the muscular attachments and the character and direction of the force. Hamilton says: "It is more common to find a transverse fracture in the middle third than at any other point of the shaft of the bone; but in the upper third the obliquity is extreme and almost constant." The obliquity in the upper portion is most marked in instances of indirect violence with torsion and muscular resistance, the lines of separation running outward and forward. Sharp direct violence at a right angle to the longitudinal axis will give a transverse fracture in the upper

Fig. 437.—Spiral fracture of the shaft just below the trochanter extending up into the greater trochanter. One large fragment is nearly loosened.

third. In the middle of the shaft transverse or slightly oblique planes occur on account of this area's being in a condition of muscular balance, while in the lower third the obliquity tends to run from behind forward and downward.

Displacement is far greater than in fracture of any other bone, on account of the length of the femur and the powerful muscles concerned (Figs. 438 and 439). In transverse or very slightly oblique fractures where separation is complete the fragments override at once, and in very oblique fracture the sharp point of the upper fragment may penetrate the muscles and appear at the skin surface, although indirect violence be the cause. Usually the lower fragment is drawn

upward and behind the upper one, on account of the muscular contraction and infiltration of the thigh, and an angularity exists directed outward and forward (Figs. 440, 441, and 442). The lower fragment rotates outward, turned by the weight of the foot and leg, and rarely turns inward. In upper third fractures the proximal fragment is, as a rule, pulled forward and outward by the muscles attached at the trochanters, the glutei and psoas, while the flexors and adductors draw the lower fragment inward and up against the upper fragment.

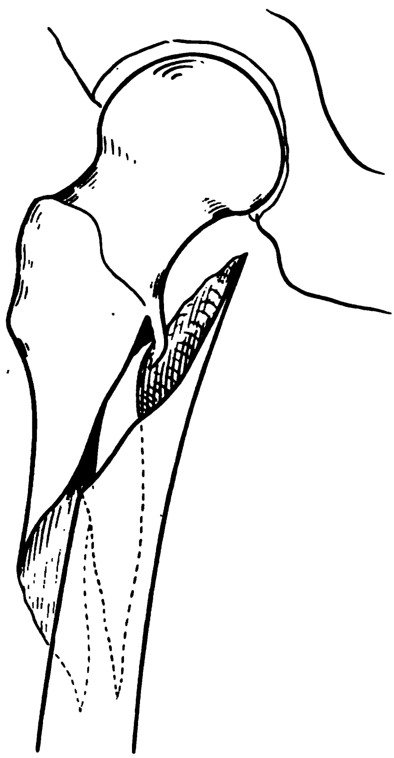


Fig. 438.—A steep spiral fracture of the shaft just below the trochanter. Note the extreme obliquity of the plane of separation.

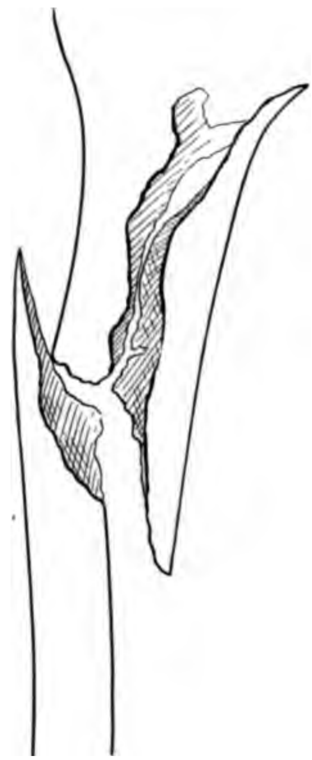


Fig. 439. — Oblique comminuted fracture of the upper end of the shaft. Compressional violence aided by torsion the cause. Note the overriding.

If the periosteum remains intact in one part of the fracture holding the fragment ends together, the shortening results from the angularity of the fragments; but if the periosteum is ripped off either fragment sufficiently to allow a slipping by, or is torn completely, shortening in addition to angularity is caused by the overriding. Rotation is present in all cases.

The pathology of the complications is small in simple fracture, in spite of the opportunity for interposition of muscle and fascial fragments in the large thigh. Very rarely are vessels and nerves

injured except in the lower third, where the vessels take a course directly behind the bone and can be injured immediately or suffer damage later from pressure or septic thrombosis. Gangrene of the extremity frequently follows. On account of the usual displacements and obliquities of the fragments little damage is done to these structures even if the fracture is opened by penetration of the sharp points from within outward. Open fractures and gunshots of this bone lead to all the displacements and complicating pathology mentioned in the general chapter on Pathology (Fig. 443).

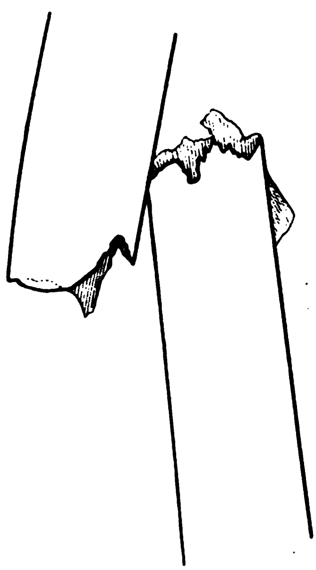


Fig. 440

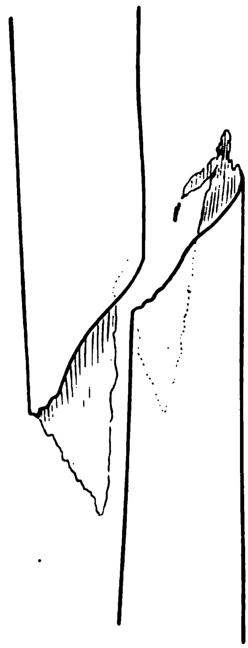


Fig. 441

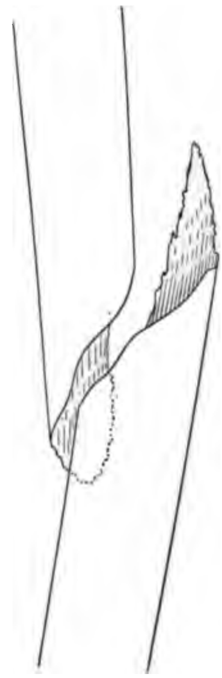


Fig. 442

Fig. 440.—Transverse fracture of the upper part of the femoral shaft. The displacement is marked and is difficult to reduce on account of muscular contraction.

Fig. 441.—Oblique fracture of the upper part of the femur. Lower fragment drawn upward and backward.

Fig. 442.—Spiral fracture of the upper part of the femur. The sharp points become imbedded in the muscles.

Non-union in simple fractures of the shaft treated conservatively is rare. Non-union is frequent following operative interference if there is infection. Mathews[1] records a case of a woman, aged fifty-one years, who twenty-three years before had sustained a simple fracture of the middle third of the femur (Figs. 444 and 445). This never united, probably on account of improper treatment, but after seven years she could get around quite well. At the time of the report she had no bony union between the fragments, which were freely movable, and

[1] Ann. of Surg., li, 579.

the leg presented a shortening of four inches. In spite of this she could walk a distance of five miles without aid and with no discomfort. Delayed union of the shaft is also rare but malunions with deformities at all angles and much shortening are common. These are for the most part caused by faults of treatment or lack of coöperation of the patient with the attendant. In children malunions are

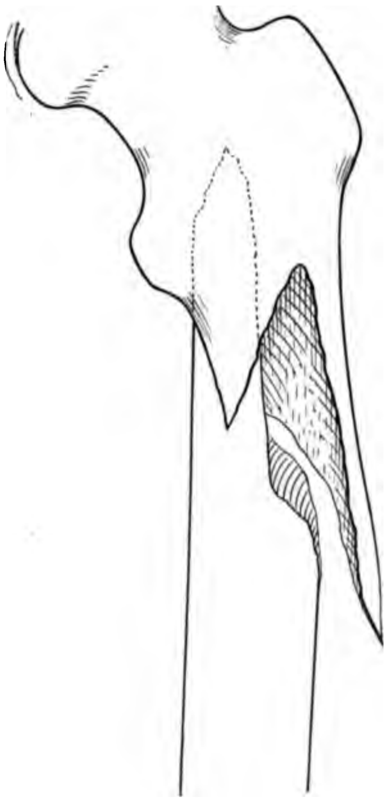


Fig. 443

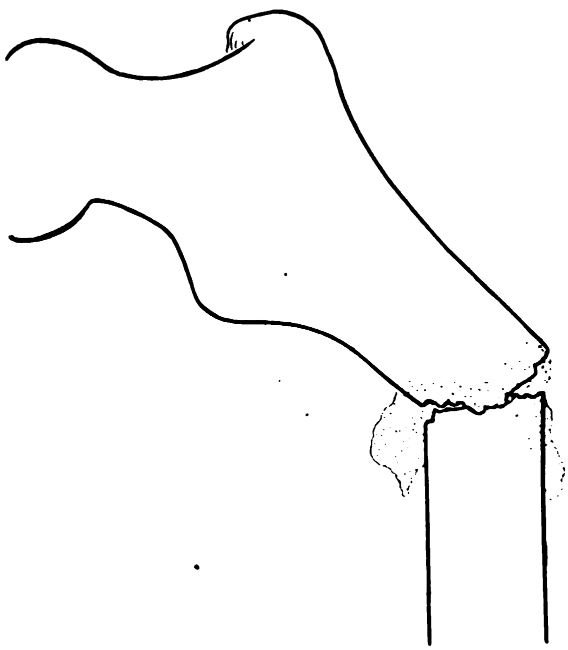


Fig. 444

Fig. 443.—Spiral fracture of the upper part of the shaft. Marked shortening and rotation of the leg inward.

Fig. 444.—Non-union with angular deformity and great shortening in an adult man's femur. There seems to be considerable callus. After four months it was operated on. See following figure.

liable to occur if the dressing used is not carefully watched and properly replaced when disarranged (Fig. 446). Adults who are ignorant, alcoholic, or otherwise unruly, by not coöperating, can ruin the very best effort made looking toward proper repair of shaft fracture. Judd[1] details some interesting cases of this character. I recall one case at Mercy Hospital in which the patient tore off the plaster used for

[1] Railway Surg. Jour., 1914.

extension not less than four times for no other reason than that he did not like it and obtained a marked shortening and angular deformity as a result.

Pain, effusion into the knee-joint, and later stiffness are found in about 60 per cent. of shaft fractures. Sprains received in the knee area with ligamentous tearing at the time of fracture, especially by

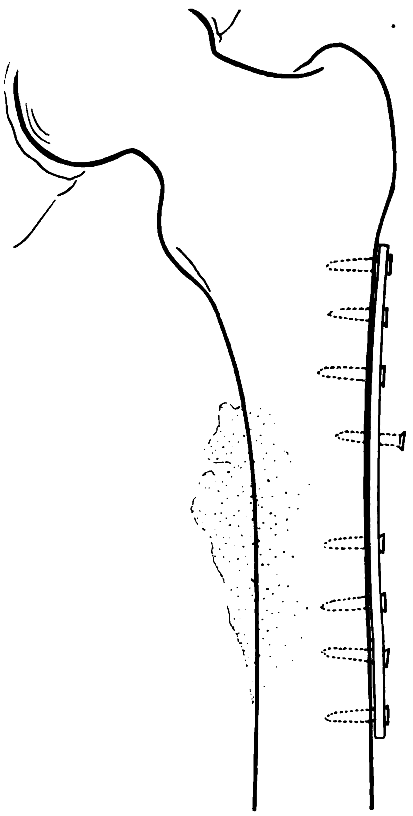


FIG. 445

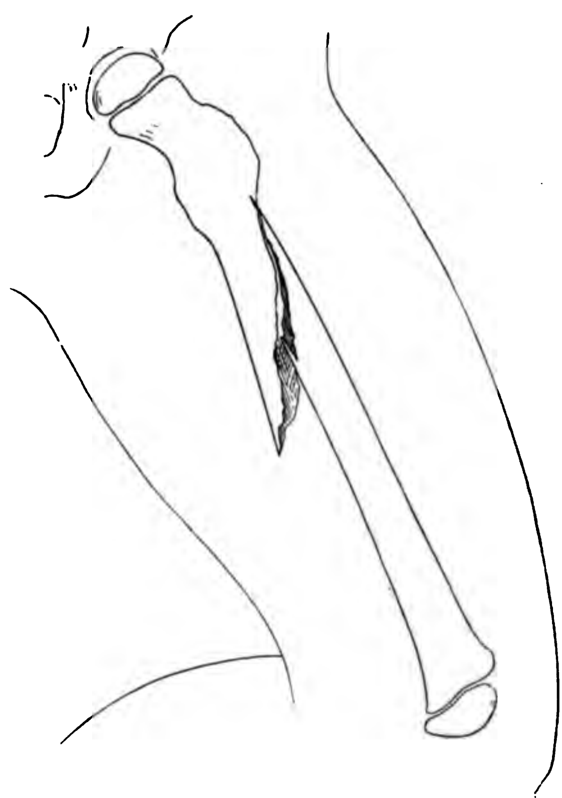


FIG. 446

FIG. 445.—Operative repair of preceding non-union. The projecting screw was not turned up because the slot in the screw head failed to hold the driver. Perfect apposition and length. Plate now in leg over three years with no irritation.

FIG. 446.—Oblique fracture of the femoral shaft in a child. I am more in favor of treating this by coaptation splints and straight Buck's extension than by suspension at a right angle. It is almost impossible to overcome the effect of the limb's weight.

indirect violence, explain many of these results; passive congestion from the obstructed circulation at the site of fracture or the pressure of extravasated blood between the fascial spaces account for most of the others which make their appearance within three or four days after the accident. Later effusions, both intra- and extra-articular, are probably brought about by the prolonged immobilization with sudden circulatory changes following passive motions or relief of splint

and bandage pressure. Chronic periarticular changes with infiltration and lack of muscle power may terminate in a permanently weakened and thickened joint with evidence of excess joint fluid present for years. Vigorous children and adults overcome this tendency in a few months. Aseptic aspiration with injection of glycerin formalin 1 per cent. or simple strapping may cure this condition.

Symptoms and Signs.—The symptoms and signs are loss of function, pain, deformity, false point of motion in the thigh, crepitus and shortening of the thigh. Unless the patient is thin it is very unsatisfactory to attempt to outline the bone continuity by palpation, but the complete loss of function with the foot lying turned over on one side or the other, the pain and apparent deformity, even in fat subjects, make diagnosis sure. The length of the thigh or whole leg can be measured, as indicated in this chapter in the discussion of fractures of the neck, or if the shortening is to be strictly localized the measurements from the anterior superior spine to the lower border of the patellæ can be computed. The position of the trochanter in its normal place will differentiate fractures of the neck or dislocation. Shortening may vary from a small fraction of an inch to four or five inches.

Crepitus is inconstant and not worth searching for, unless it is accidentally demonstrated in the course of the examination. To determine the false point of motion in the thigh the attendant may find it sufficient to rotate the leg by grasping the foot, when he will discover that the trochanter does not turn with the shaft, or by placing the flat hand beneath the thigh at the suspected point of fracture, holding down the upper part of the thigh and lifting, he can demonstrate the loss of continuity at once. Deep palpation avails little and is painful.

Prognosis.—The prognosis in fracture of the shaft is of interest in three main directions: (1) First to be considered is danger to life, which is the most important, and is a serious question in open fractures especially. These are accompanied by much violence, shock, or hemorrhage, and this factor in the prognosis takes first place. Life may also be threatened in patients forced to lie in bed for the six or eight weeks of time needed for union where treatment is by extension or plaster casts, or in instances of refracture following falls upon patient's first starting to walk after healing. Ashhurst and Newell,[1] in 26 cases of fracture of the shaft, had 5 deaths, caused by delirium tremens, pneumonia, and injuries elsewhere.

(2) Next to be considered are good functional results alone. These are secured by bony union, generally with shortening and slight limp, compensated by the pelvic and spinal inclination. End-to-end or anatomical approximation is not necessary for the attainment of this result. Ashhurst and Newell studied 121 cases at the Episcopal Hospital, Philadelphia, to contrast conservative treatment with operative treatment, as they felt that the former had not received due attention

[1] Ann. of Surg., xlviii, 748.

in regard to functional result. Their end-results showed that only 4 cases were completely incapacitated (all parts of the bone), while 28 had perfect functional results with no limp or any hindrance to normal use of the limb, and of 41 examined for shortening, 8 showed normal length of limb.

Good functional results are the rule after conservative treatment; shortening always exists but may be very small and not noticed. Non-union and excess callus—Estes found it in less than 10 per cent.—are not common. Following different methods of treatment I frequently find a large callus, which slowly absorbs in a few weeks and causes no interference with function or circulation. The only method by which one can be sure of no shortening is the open treatment. Those who assert they can obtain a normal or even longer leg than its fellow by continuous traction do not consider that much of this length is obtained at the time by ligamentous stretching at knee, hip, and ankle, and that it is not permanent. True end-results taken after the patient has used the limb in walking for three months give the final length, and the statement made above is made with this fact in mind and based on many cases. I have seen many examples of limbs giving the same length while one is in extension, or even when first out of the permanent dressing, which show decided shortening in a few weeks after walking was attempted.

Of almost equal importance with preservation of proper length is the preservation of the weight-bearing axis of the leg, that is, the avoidance of inversion or eversion of the foot which would destroy the weight-bearing line, from anterior superior iliac spine through the patellar centre to a point between the great and second toes. Inversion is a better final result than eversion, as in the latter the weight-bearing line falls inside the great toe, and pronation of the foot, and strain on the internal lateral ligament of the ankle and knee follow with functional disturbance.

(3) Finally good functional and satisfactory cosmetic results must be considered. People will desire to see the roentgenograms of their bone injuries and in addition to their functional result demand cosmetic results, that is good end-to-end reposition of the fragments without deviation of the angle of support. This is the ideal result to be sought; normal length is maintained and the patient does not have to learn new balancing habits or muscular tricks to get about.

Estes[1] studied end-results in 760 cases, 700 of which were reported to make satisfactory recovery. 200 of these cases were checked by roentgenograms, but only 2 per cent. showed perfect restitution of fragments, except in the operated cases. An average shortening of three-fourths inch resulted, and this has been adopted more or less as a standard indication of acceptable outcome. The axial displacement as indicated by inversion or eversion of the foot was recorded in 463 cases, 370 of which showed no such displacement, so that our

[1] Ann. of Surg., lvi, 162.

prognosis should favor no deviation in three-fourths of the cases and not more than three-fourths inch shortening on the average. The average length of time in bed was 8.2 weeks; of subsequent use of crutch and cane eight weeks; the death rate was 3.69 per cent.

Treatment.—Considering fractures of the shaft as either open or closed the treatment divides itself into: (1) the application of dressings and splints, including Liston splint, Buck's extension, Hodgen's splint (see Fig. 33, in chapter on Treatment) double inclined planes and railroad splints, Thomas and Rainey splints, ambulatory and plaster-of-Paris splints and casts; (2) operative treatment, including simple reposition, nailing, Lane plates, intramedullary bone and ivory splints, Steinmann's and Codivilla's nail extension and Ransohoff's modification with ice-tongs. The reader is referred to the remarks in the general chapter on Treatment and the previous remarks in this chapter on the Femur for details not given here.

Immediate care in closed fractures is like that given fractures of the neck by lateral padded support or by simple fastening to the

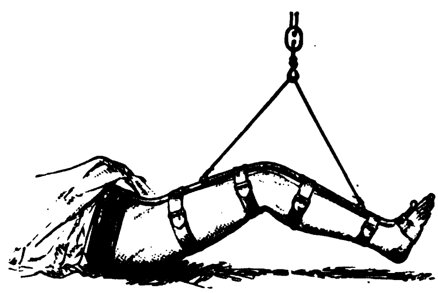


FIG. 447.—Nathan R. Smith anterior suspended splint for fracture of the femur. No enclosing bandages are shown on the limb. (Stimson.)

fellow limb until the point of permanent treatment is reached. If alcoholic delirium, other grave injuries, unruly condition, or mental disturbance demand restraint, the Liston splint of padded wood extending from the axilla beyond the foot can be used until the condition improves. Buck's extension applied from a point below the site of fracture with a sufficient weight (fifteen to thirty pounds) can be used alone or in combination with the railroad splint, or the Hodgen's gutter splint (Fig. 447). Anterior splints suspended from above and combined with traction are not favorites in general use. They are valuable, but the railroad or gutter splints are better. Double inclined planes can also be used, but are not comfortable, so that the patient often twists around, destroys the angle of the replaced fragments, and interferes with the result. Traction can be applied from a point below the site of fracture extending out beyond the knee to a pulley and weight; a smaller weight must be used on account of the limited area of attachment of the plaster on the thigh. The railroad splint by its movability is to be preferred to the double inclined

plane, as it takes up the patient's movements in part and with the leg horizontally extended permits a much heavier weight. Simple Buck's extension with the foot of the bed raised, aided by close-fitting, coaptation splints at the fracture site, make first-class traction and treatment until callus has formed. Slight abduction can be maintained, and by careful watching the axis of weight bearing can be perfected. A suitable pad should be placed beneath the injured trochanter to avoid rotation outward of the upper fragment. Support of the body of the thigh in instances of swelling and contusion can be given by long, narrow sand-bags or an anterior moulded splint of plaster, and when inflammation subsides in a few days the coaptation splints can be applied.

When the fracture is high up on the shaft and the upper fragment is flexed, the railroad splint or the Hodgen's splint and extension are very comfortable and favor reposition of the broken ends of the bone (see chapter on Treatment). Prolonged traction pulls the fragments into line until shortening is largely overcome and the contusion effects at the site of fracture disappear. After four or five weeks the patient may be anesthetized and further reduction accomplished by mechanical or assistant's traction and manipulation, after which a body cast of plaster of Paris will hold the position obtained. As before noted, the plaster spica will not maintain abduction of the leg, and if this is desired the cast must extend to the knee on the opposite side. If at the expiration of six weeks the plaster spica is applied with the leg in good position, the patient can be permitted to get up and use crutches after the plaster is thoroughly dried and manifests no tendency to crack across the groin. A lift of three or four inches is put on the sole of the sound foot so that no weight can possibly be borne on the injured leg to cause shortening or break the cast.

Plaster of Paris is not used for first dressings of thigh fractures, as it formerly was. It does not allow correction of shortening and is not needed to maintain position of the bone while the patient is in bed and is not enough protection to warrant the patient being up and about from the first. The tendency for body casts to crack across the groin can be counteracted by using many vertical layers of the bandage across the abdomen or thigh or by incorporating laterally in the plaster a long piece of inch iron or steel rodding.

The Rainey splint is applicable to many cases, especially when the upper fragment tends to rotate out. Buck's extension can be combined with it. The Thomas splint, as mentioned in fractures of the neck, is an excellent one, allowing extension and any degree of abduction and the correction of angular deformities at the site of fracture by the application of bandages or adhesive plaster. It is particularly useful with infants, even more so than the vertical extension, as it enables them to be picked up, splint and all, and carried about with no fear of disturbance of the fragments. In small children, up to an age of understanding, the treatment most used is by vertical extension with the Buck arrangement and a suitable weight. If one leg alone is thus

suspended, the patient is inclined to twist about at all angles or support himself by raising the body weight with the other leg flexed at the knee, and consequently both legs should be suspended with enough traction to elevate the buttocks slightly from the bed. This arrangement allows for care of the patient. Blair[1] suggests that the position for infants in the treatment of complete flexion of the thigh on the abdomen should be maintained by a splint of galvanized steel made from a cardboard model. This looks like a large letter Z, is heavily padded and can be removed each day during the bath by the mere holding of the leg in complete flexion. Complete flexion of the thigh maintained by broad diaper or bandage is often very satisfactory in infants.

Infants and small children are usually treated by suspension of the legs at a right angle to the body lying in bed. One or both legs may be elevated, held by Buck's extension attached to a rope and pulley. A longitudinal bar is erected over the crib or bed and the pulley is inserted in this—the weight hanging clear of the bed. Enough weight is applied to lift the buttock slightly from the bed surface. When the child is bathed or the toilet is attended to, the bed-pan can be slipped under easily because the weight takes up the slack in the relaxed rope and the bone fragments are not disturbed. Little patients who are not watched twist and turn about in the bed if only one leg is extended, so that both legs should be included in the dressing when there is no special attendant.

Silver[2] has combined the Bradford frame and extension in a very useful manner. The gas-pipe frame is made about four inches longer than the patient and a little wider than the shoulders; at a point opposite the hip-joint when the child lies inside the frame a T-connection is tightly screwed into the pipe. To this connection is attached a piece of pipe long enough to reach about four inches above the suspended foot. An L-connection capped at the end furnishes the terminus for this projection. The canvas covering the frame is made from one piece, a hole being cut for the passage of the upright described. If the surgeon desires to suspend both legs the frame can be shorter, as it does not have to care for one leg lying extended, and the terminal piece of the upright is longer.

Adhesive extension is applied to the leg, as in Buck's extension, and the ends of the straps are fastened to the transverse terminal bar, so that the buttock of the affected side just clears the bed. The leg can be steadied by carrying the diaper around the upright piece or an adhesive strapping can be applied around the groin and the base of the upright. Small coaptation splints can be used around the thigh if needed. The upright iron pipe protects the leg from accidents.

After four weeks union is established, and the young children are put in a body plaster cast with the lift on the opposite foot and allowed to get around on crutches (Fig. 448).

[1] Surg., Gynec. and Obst., May, 1914, p. 645. [2] Ann. of Surg., xlix, 105.

Spiral fractures, long, sharp fragments of which penetrate the muscles at any portion of the shaft, are difficult to replace and hold in position. Each case must be handled and manipulated in accordance with the findings of the displaced fragments, and roentgenogram to check the reposition is indicated. Anesthesia and manipulation may satisfy the surgeon that he has obtained bony contact and fair reduction, but if any doubt exists, or the deformity cannot be reduced, this class of cases should be treated by open operation and careful alignment. In the upper third the lower fragment is inclined to pull inward and upward and its sharp upper point extending toward the hip-joint, and slight torsion at the time of accident will frequently break off an outer third fragment. At the lower extremity the sharp upper frag-

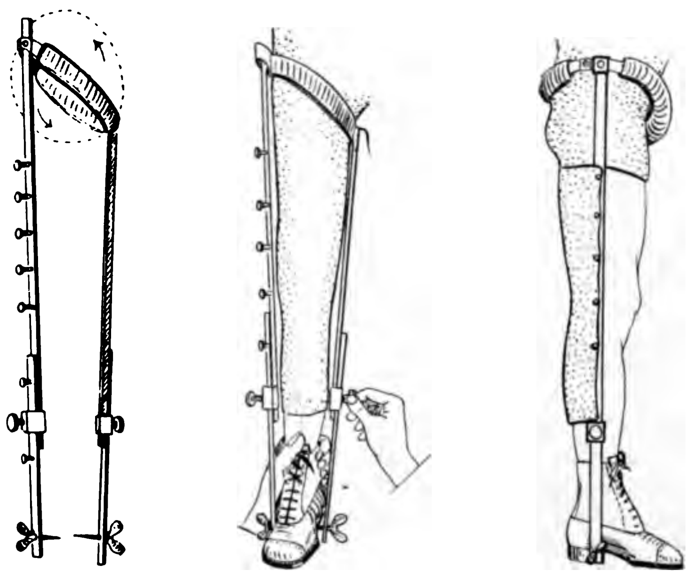


FIG. 448.—The Englemann splint for primary and secondary treatment of femur and leg fractures. Extension is supplied by the perineal band and the sharp points which fasten into the heel of the shoe. The splint's side rods are adjustable.

ment is driven forward into the quadriceps extensor muscle and is separated from the lower fragment, which is pulled down by the gastrocnemius and may tear the artery and vein. If the limb is cold or shows no circulation and gangrene threatens, open operation should be done at once, the condition of the artery determined, and the advisability of amputation decided upon. Fortunately these cases of bloodvessel injury are very rare, and early open operation to fix the fragments with careful after-treatment will save many limbs.

When union is delayed beyond the usual ten or twelve weeks all constitutional disturbances should be inquired into, and corrected, and in addition the patient should be placed in a body cast and allowed to be up each day in order to aid the circulation in the limb, and to

bear a slight weight on the bone, but weight-bearing should be controlled by checking measurements on the length of the limb to avoid further shortening. Late union nearly always follows, and if operation is contra-indicated or refused union should not be despaired of for at least nine months. Non-union, except where there is great overriding, intervention of other tissues, or some dyscrasia, is rare and should be subjected to open replacement if no distinct reason against this step exists.

Open fractures of the femur are always grave injuries, even when opened from within by a pointed fragment. Cases made open by the causative violence suffer much laceration of tissues and comminution of bone and frequently entail amputation. The injury to bloodvessels and nerves, danger of infection and deep-seated abscesses in the muscular and fascial planes are apparent, and drainage of the fleshy thigh is not easy to attain. The Lambotte method is excellent treatment for these open fractures. Lilienthal[1] advises the fixation of the fragments by long-handled gimlets screwed into the bone remote from the site of fracture, reduction being made by two pieces of steel rod applied to the line of gimlets, the whole being bound together by plaster of Paris which has been previously sterilized by baking. The open wounds are carefully disinfected, and no sutures are used in the soft parts, but a packing is put in as if osteomyelitis already existed. After two or three weeks, the gimlets are removed, and the wound edges, now granulating, are brought together by adhesive plaster. This makes the procedure quite safe from the septic standpoint, will improve the functional result, and shortens convalescence. Other methods are given under Operative Treatment.

Routine treatment as described in the chapter on General Treatment is the more conservative. A minimum of handling consistent with reduction of fragments within the soft parts, removal of foreign material and the control of hemorrhage followed by a copious absorbent dressing with drainage is good practice. The limb can be cared for on a double inclined plane or a suspended Hodgen's splint. After danger of sepsis is past and the wound starts to close, the body plaster-of-Paris cast can be applied or extension with weight in attempt to overcome shortening. If malunion or great deformity results, open operation looking toward correction should be performed.

Ambulatory splints—see chapter on Treatment.

Operative Treatment.—Fractures of the shaft of the femur are most favorable for open treatment on account of the importance of this bone to the individual's activity, its relatively easy access without damage to the soft parts, the large size of the bone and the ease with which strong traction and manipulation can be applied. Estes,[2] in his canvas of the American Surgical Association, found that only four out of thirty-five surgeons were opposed to open operation in any case, and thirty advocated it only in case evident proper restitu-

[1] Ann. of Surg., 1912. [2] Loc. cit.

tion had not been accomplished. He names the following five difficulties hard to overcome unless operation is undertaken:

(1) Muscular spasm, which was overcome by anesthesia.

(2) Locking of fragments by leverage or gravity.

(3) Interposition of fascia, muscles, etc.

(4) Persistence of shortening even after the muscular spasm is overcome.

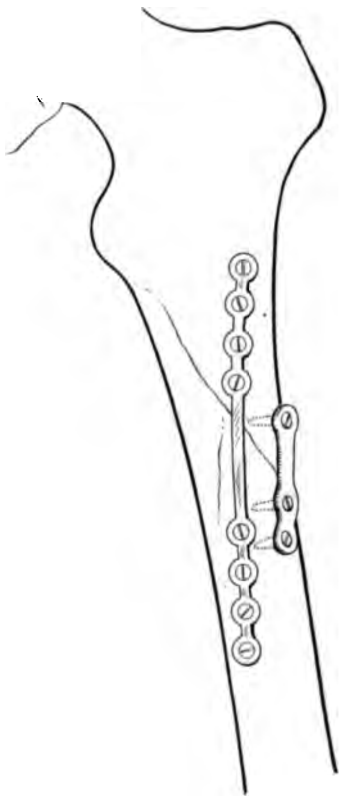


Fig. 449.—A spiral fracture of the femur which extended 9 inches. After the first large plate was adjusted a second smaller plate was used to bridge over the fracture plane to give added strength. The result was excellent with no shortening.

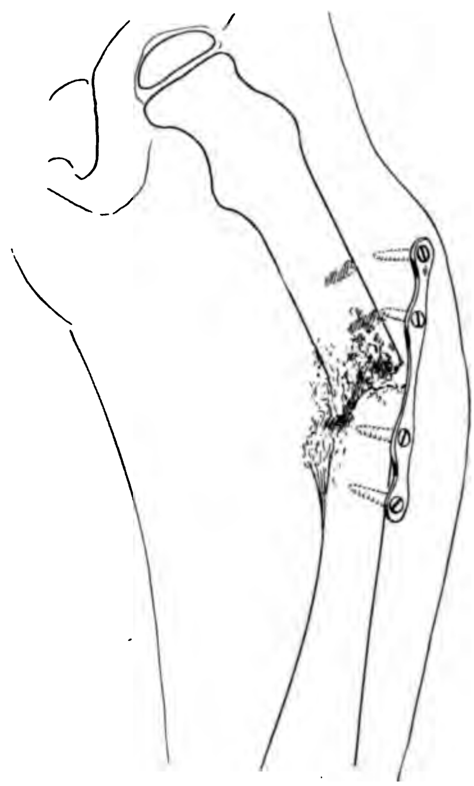


Fig. 450.—An example of unfortunate result in plating. The operator selected a patient on whom it is unwise to place a Lane plate, a young child. The plate was not strong enough and the bone became infected. Note the deformity of the leg, the screw tracts from which the screws have pulled and the bulging plate presenting just beneath the skin.

(5) Preservation of reposition of fragments until a fixed supporting dressing is applied. Anatomical reposition, the criterion of cosmetic result, is not obtained in more than 1 or 2 per cent. without open operation. But the dangers of operation by other than those skilled in this work are to be pondered in every case in addition to the arguments given in the chapter on Operative Treatment.

Technic.—Approach from the lateral aspect of the thigh by a long incision in the axis of the femur gives quick and complete exposure of the fracture at any site from the greater trochanter to the knee. If

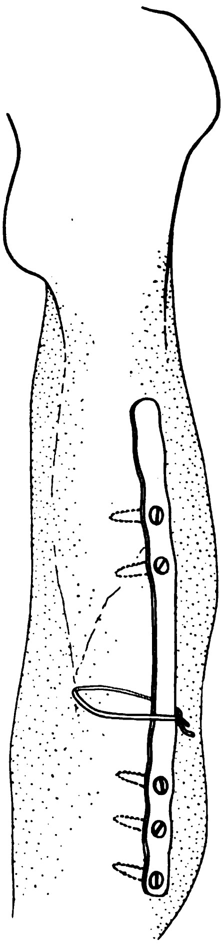


Fig. 451. — Another unfortunate example of plating plus wiring. The anatomical result good. The great hypertrophied mass of bone is the result of the infection. I imagine this plate was put on beneath the periosteum which was raised and then sutured over.

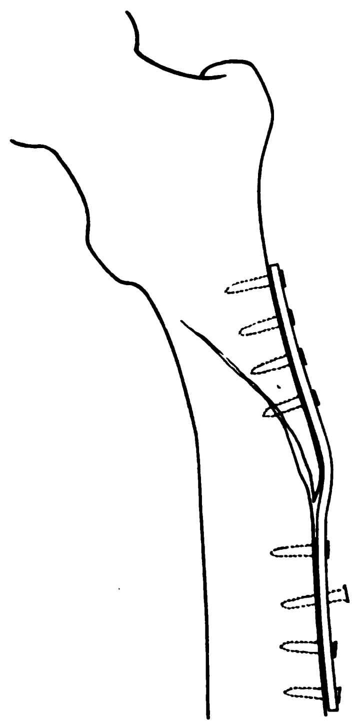


Fig. 452.—Faulty result after plating caused by conditions beyond control. After operation this case was in perfect alignment. He was left in other hands and the cast was removed too soon. The plate had to take up the strain of weight-bearing and while it held in its attachment to the bone it bent slightly, An aseptic result.

a Lane plate is the choice of fixation and much overriding is present, the patient should be placed on the pelvic rest and extension from the ankle with some mechanical apparatus provided for before the incision is made. The fragments are isolated as in the fracture of the

humerus and by manipulation and traction are brought into alignment. Oblique fractures are to be aligned and clamped in position while a plate is affixed or a wire is thrown around. I do not believe wire has any place in the treatment of fractures of the shafts of long bones; it will not hold any tension nor does it immobilize the fragments. It has a use in holding on detached fragments that cannot be included under a plate. Long plates, sometimes two, are needed to hold oblique fractures (Figs. 449, 450, 451, and 452). Nails are not of much service in fractures of the shaft, unless the break is oblique or small fragments are attached. In cases with much deformity and callus formation they are of use when a plate cannot be applied or infection exists in the bone.[1] In transverse fracture use of the intra-

FIG. 453.—Repair of a transverse fracture of the shaft by an intramedullary splint fashioned from a fragment of bone found loose in the fracture site. Note the deficiency in the outer part of the shaft caused by removal of the loose piece.

medullary splint is the best and easiest treatment, as it can be done quicker and through a smaller incision and gives absolute anatomical reposition with less disturbance of the parts than any other method (Figs. 453, 454, 455, and 456). Simple reposition may be sufficient where the fragments are of such a nature that they can be locked together and where possibility of their slipping out of place while the external dressing is being applied is remote (Figs. 457 and 458). After plating, a firm body cast is indicated with the limb in a position favoring the least strain on the internal splint. After intramedullary splinting either a cast or a Thomas or Rainey splint can be used, but always some secure external support is needed.

[1] Murphy, Clinics, i, 853.

Cases of malunion or delayed union demand freshening of the site of fracture, removal of excess callus and reaming of the medullary cavity if an intramedullary splint is used. External splints in these cases should be left on half again as long as in ordinary cases, that is, from twelve to fourteen weeks.

Accessory instruments for the approximation of the fractured ends have been described by Gerster. He used a bicycle chain with a hook or turnbuckle to spread the ends apart that they might be brought into alignment. Edward Martin has suggested the use of a stout piece of sterilized muslin fitted cap-like over the upper end of the lower fragment, on which traction can be made and the bone brought

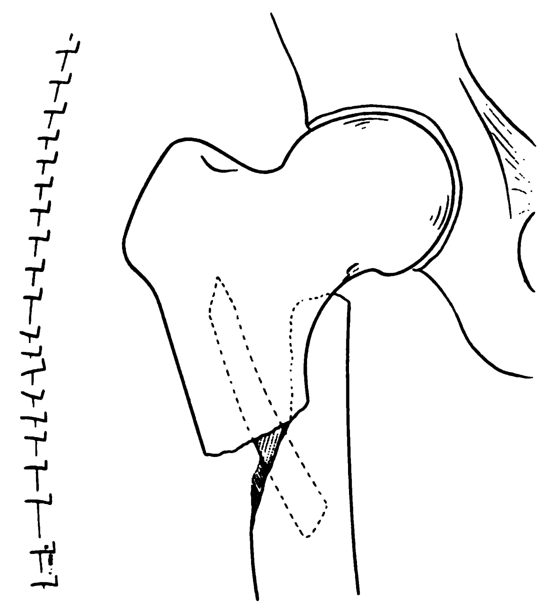


FIG. 454.—In handling the patient the postoperative cast was broken and the bone peg slipped and permitted overriding. A longer bone peg would not have allowed this, but might have broken (see Fig. 488).

into alignment. These devices introduce more material into the open wound and give more chance of infection. The more modern means of mechanical extension applied from the foot or leg, or the device of turning the bone ends out from the wound for inserting the intramedullary plants are simple, more efficient, and cleaner than these. Cases with three or four inches shortening have been brought into alignment with ease by the author without the use of these methods of extension and by intramedullary splinting. Lambotte's method (refer to chapter on Operative Treatment) has been little used in America, but bids fair to be popular and useful in open fractures. Murphy,[1] reporting a case of infected open fracture just above the

[1] Clinics, ii, 617.

condyles with non-union and overriding of the patella by the lower end of the upper fragment, made use of two phosphor bronze plates implanted at right angles into the two fragments in slots made with a rotatory saw. The upper fragment was resected one and three-quarters inches and the lower fragment squared off to meet it. Good apposition with union and 10 degrees voluntary motion in the knee was obtained after nine weeks.

FIG. 455.—Final result of the operation illustrated in the two preceding roentgenograms. There is no apparent deformity, and shortening is about ½ inch. The board end placed under the injured heel exactly overcomes the shortening.

There are other methods which are really operative in character and which do not open the site of fracture:

(1) In Codivilla's nail method a nail is driven through the os calcis and to it extension is applied directly to draw out the femoral or leg fragments. Josserand, Rendel, and Michel[1] report 4 cases treated in this manner. The ages varied from six to fourteen years and the amount of weight used from 8 to 15 kg. One case was described as

[1] Revue d'Orthop., November, 1913.

a perfect recovery. All showed 1 cm. shortening, 2 bowing of the femur and 3 pulling of the nail through the os calcis so that it was held by the plantar tissue alone. Case 3 showed some loss of bony tissue in the os calcis after the nail pulled through, together with two small exostoses.

(2) Steinmann's nail extention method[1] has been tried out by Gerster, Bartlett, and myself in America.[2]

FIG. 456.—Side view of the patient shown in the preceding figure. Note the amount of voluntary flexion and the faint operative scar on the thigh.

Technic.—A drill or nail eight inches long and about 4 mm. in diameter is inserted horizontally about a half-inch above the external condyle of the femur by the operator first pulling the skin upward, the nail penetrating clear through the thigh. Iodine, desiccating powder, and collodion are put over the points of exit, and gauze transfixed over the ends completes the aseptic dressing. To avoid rotation of the leg one end of the nail, generally the outer, can be supported

[1] Zentralbl. f. Chir., 1907, p. 938. [2] Am. Jour. Med. Sci., August, 1913.

by a wire from a bar above the patient. The main extension with a weight of eighteen to twenty pounds is in direction of the longitudinal axis of the thigh and is obtained by wires or tongs applied to the ends of the nails, which project an inch or more beyond the skin. The thigh is maintained in semiflexion and the heel is not allowed to touch the bed. In its insertion the nail should avoid the medullary canal, the hematoma at the site of fracture, the joint capsule, and the epiphyseal line; hence it is placed, as mentioned, just behind the middle line of the bone. When the fracture site is in the lower third of the

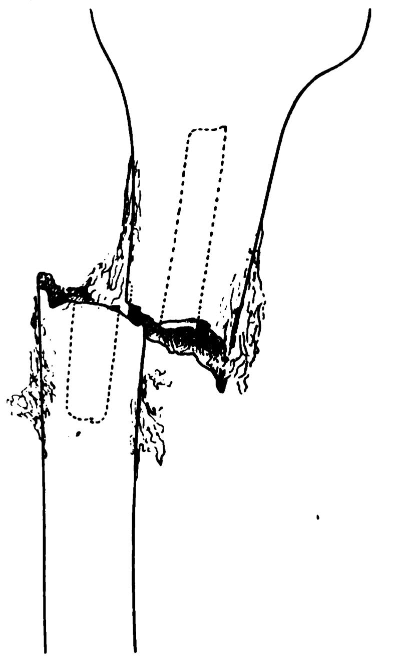


FIG. 457.—A case of refraction following operative repair by intramedullary splint. There seems to be sufficient callus. Fracture passed squarely through the bone peg disproving any weakness on its part but proving the action of a force which refractured in spite of its presence.

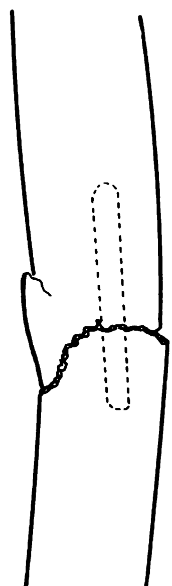


FIG. 458. — Repair of a transverse femoral shaft fracture by an intramedullary peg.

femur the nail is inserted through the upper end of the tibia about one and a half inches below the joint surface. By this extension, which needs to be greater in old than in recent cases, and in which less weight is needed than in other methods and yet more weight can be used, the traction is continuous and painless when once in position. Steinmann asserts that through it the fragments can be better controlled than by any other means except open operation, that shortening is usually overcome in one week, and that no cases of delayed union have ever resulted from its use. Passive and active motion is used within five days after the extension is applied, and there are none of the later

knee disturbances caused by stretching of the ligaments. The extension should never be used for more than five weeks, the usual period being three weeks. To remove the nail, the operator paints one end with iodine, then grasps the other, rotates it to loosen it and pulls it through. Iodine being squirted into the holes and a dressing applied, the wounds heal promptly within a week. Some cases run a fever from 1 to $1\frac{1}{2}$ degrees while the nail is in position. If the lower fragment is displaced posteriorly, it can be supported further by extension to the thigh at right angles from above, but Jones believes that in this deformity after fracture, extension in the long axis ultimately brings the fragments into line.

As the limb straightens out and lengthens, if the weight becomes irksome, it can be released for a few hours and then reapplied, but a condition of extreme lengthening, possibly 1 cm. more than the well thigh, is to be attained; when callus is well established, the extension is removed in three or four weeks and a moulded plaster or Steinmann's hip splint, with the upper margin encircling the thigh and resting on the pelvis and the lower end impinging on the nails, is used.

The greatest objection to this method is the possibility of infection in the nail wound. This would occur shortly after insertion or three or four weeks later, and while it is relatively easy to put the nail in aseptically, it is not so easy to maintain it so. However, all of Gerster's infections have remained localized, and no fatal cases are reported where Steinmann's technic is adhered to. One fatal case has been recorded in which the hematoma about the fracture was entered, and thus an open fracture really made. Shortening of as much as 11 cm. has by this method been overcome and in cases of as long as forty days' standing. In malunion with overriding open operation can be done to free the bone ends and the nail extension then applied, but if one takes the risk and trouble to open the fracture, it is the author's opinion that extension can be procured by mechanical means and a plate, or intramedullary splint, used at once. Gerster reports 11 cases which do not seem to offer any better results than those handled by other treatments and not so good as those treated by use of the internal splint.

(3) The nail extension method has been modified by the use of ice-tongs driven into the femur with extension applied to the handles. Ransohoff[1] reported 3 cases treated by this method after he learned that 2 out of 13 cases of fractured femur plated at the St. Louis City Hospital died. This apparatus is applied and used like the Steinmann.

Supra- and Intercondyloid Fractures.—These are described together, as they are so frequently associated. The plane of fracture may be at any height above the condyles and be transverse or oblique, much as in the case of the humerus above the elbow-joint. The main fracture through the shaft is generally oblique from behind downward and forward, and the separation may be little or very great with the

[1] Trans. Amer. Surg. Assn., 1912, xxx.

upper fragment driven down toward the knee, the lower fragment riding upward and posteriorly, pulled by the gastrocnemius into a position of flexion (Figs. 459, 460, and 461). In addition to this simple displacement the lower fragment may suffer a split through its substance in the intercondyloid notch. This split may be but a line, or the separation may be complete and extensive, so that the two parts of the lower fragment are spread laterally, the point of the upper fragment extending down between them, holding them apart. The

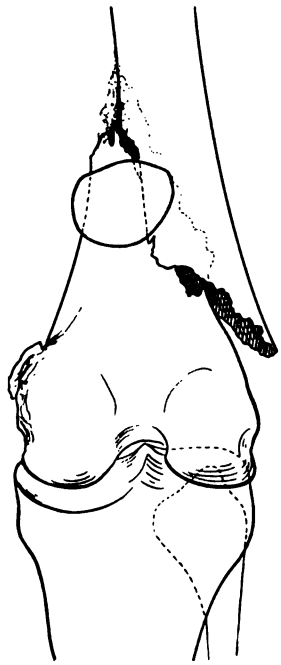


FIG. 459.—Oblique supracondylar fracture of the femur with evidence of fracture by direct violence on the internal condyle. There is considerable overriding and the patella seems to lie very high on that account.

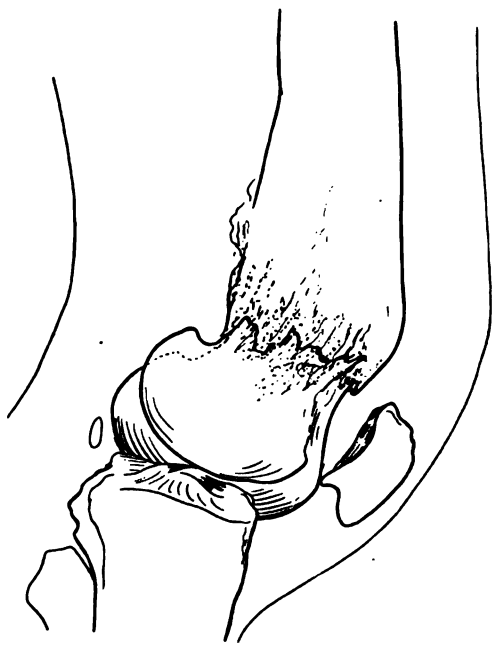


FIG. 460. — Healed transverse supracondylar fracture with deformity. Note arthritic change involving the patella and tibia.

patella sinks into this separation, if the hiatus is wide enough, and if the crucial ligaments are torn, a subluxation of the tibia backward on the lower fragment exists (Figs. 462 and 463). As the support above the knee is lost, the leg can be twisted or rotated to either side, and great deformity, shortening, and displacement of all fragments are found. If the cause has been a fall from a height with the patient striking on the knees, rather than direct violence with twisting, the sharp lower end of the shaft fragment penetrates the muscles and skin anteriorly and causes an open fracture. Or, as mentioned, this

fragment bursts into the subcrural pouch of the knee-joint, opens the joint widely, and comes to rest against the patella or the upper surface of the tibia.

Additional pathology concerns the joint and the vessels. The joint always becomes swollen and distended even though not penetrated, or though the lower fragment is not split. The effusion into it in severe injuries is pure blood; in milder cases the transfusion takes the

FIG. 461.—Spiral supracondylar fracture. Point of the upper fragment driven down into the joint and against the patella.

character of serum or excess normal joint fluid. The joint findings gradually subside if no infection follows or the fracture is not open, leaving a thickened capsule which may shrink and cause limitation of motion or a distended weakened joint. The popliteal vessels if ruptured lead to great effusion of blood around the knee, especially on the posterior aspect, but this hematoma may burrow up into the thigh and by pressure or loss of vessel continuity threaten gangrene of the leg. Rupture of smaller branches of the anastomatic arteries

causes smaller and more delayed hemorrhage, which may give as great circulatory interference.

If healing follows uncorrected displacements of this character, the knee is generally quite stiff, the thigh shortened, the leg in flexion and much permanent thickening and deformity about the knee remains.

FIG. 462.—A similar spiral supra- and intercondylar fracture entering into the knee-joint. Note the comminution and overriding.

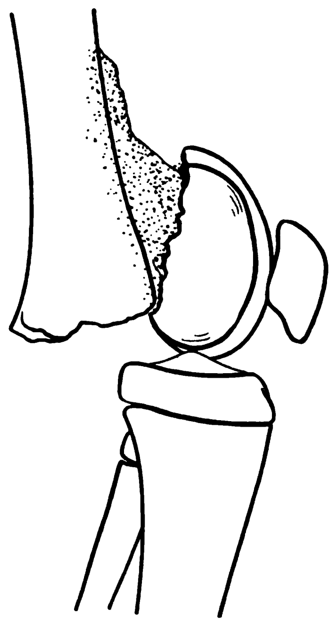


FIG. 463.—Healed fracture just above the condyles with deformity. Note the apparent anterior dislocation of the knee.

Diagnosis.—Diagnosis is not difficult. The thigh from anterior superior spine to lower patellar border is short. There is great swelling of the knee and a floating patella, if it has not been caught between two fragments of the lower femoral end, and there is independent movement of the condyles when they are grasped and mobilized, or severe pain while they are pressed together. If the ends are impacted, no crepitus can be felt, but the deformity is very apparent. Differential diagnosis must include acute traumatic arthrosis or hemarthrosis, subluxation of the knee due to laceration of the crucial ligaments or

fracture of the tibial spine, epiphyseal separation, and fracture of one condyle. Epiphyseal separations are found in younger people and are most often caused by twisting violence. Fracture of one condyle gives a rotatory displacement of the leg with a pseudodislocation at the knee and joint injuries, especially crucial ligament tears, which are described later under Tibial Injuries.

Prognosis.—The prognosis regarding full functional return is poor. The danger to life is often great and the possibility of amputation of the leg present in 10 per cent. of the cases. However, it is now better understood that these fractures, as well as those following in this chapter, are less influenced in prognosis than formerly, considered by the fact that they invade the largest joint in the body. Surgical means of caring for them disregard the joint phase of the problem much more than was formerly considered possible. Blake[1] records 20 cases of supracondyloid fracture, 2 of which were open. He believes that excepting sepsis, the greatest complications are the difficulty of maintaining reduction and the greater limitation of motion after union.

Treatment.—Simple treatment consists of reduction under anesthesia by direct extension, or extension and manipulation of the supracondylar fragments, the leg being held in flexion. This can rarely be maintained satisfactorily, and it is very risky to put on a circular cast when subsequent swelling about the knee is anticipated. Consequently a double inclined plane or the Hodgen's suspended splint are favorite treatments. In the double inclined plane extension can be applied with the leg in flexion, not so much force being needed as in fractures higher up. Moulded splints or casts applied after the reaction has subsided and kept on until the fragments are strongly united and motion of the knee-joint is painless are good treatment where satisfactory reduction can be made or operative interference is not permitted.

Operative Treatment.—Operative treatment may be demanded by the complications at the time of fracture. Laceration of the popliteal vessels may demand ligature or amputation, if both vein and artery are destroyed. In great displacement early operation offers hope of better ultimate function, provided good reduction can be accomplished. Other indications for open operation are the danger of union which will be weak and lead to impaired function, marked and persistent deformity, including shortening, spreading of the condyles, or their rotation backward.

Access to the site of fracture is obtained by lateral incision on the outer aspect of the thigh followed by retraction of the hamstring tendons and careful dissection close to the bone. The joint surfaces need seldom be entered. The fragments are exposed, the vessels identified and cared for if necessary, and by extension and manipulation of the leg under the eye the fragments can be brought into

[1] Ann. of Surg., lviii, 27.

alignment and held by a plate, or wire, or nail. Blake[1] treated 5 out of 20 cases by open operation: 1 was wired, 1 lower fragment was pried into place and held itself there, 3 were plated. All gave fair results. Fragments may be nailed on by approach from the joint surface and held in position, provided the nail or screw is set into the cartilaginous surface, so that it does not irritate the joint surface opposite. Less of this has been done in the knee than in the head of the humerus. Sherman and Tait[2] report some interesting experimental work in this field on dogs, work in which they secured perfect aseptic healing without any interference with function, using the transarticular route. They have not used the method on human beings. Handley[3] reported a case of transarticular fixation of an elbow fracture in the humerus.

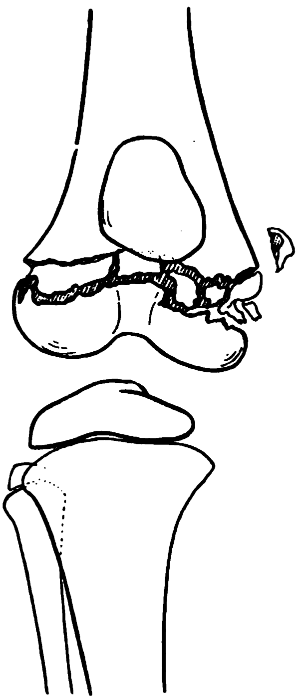


FIG. 464.—Epiphyseal separation of the lower end of the femur with some comminution.

Epiphyseal Separation.—The lower epiphysis is the first to appear, the centre showing at the ninth fetal month, and is the last to unite, some time from the twentieth to the twenty-fourth year. It may be separated at any time from birth up to twenty-one years, six and a half times more frequently in males than in females, and according to Poland, usually between the ages of thirteen to eighteen years, while Helgemeiner[4] believes between the eighth and eighteenth year. Bruns says it is the most frequent of all epiphyseal separations, citing it in 28 out of 100 cases. Poland collected 114 cases and Helgemeiner, including Poland's, found 194 cases and added 6 of his own up to 1909. Russell[5] added 8 cases and Binney and Lund[6] collected 18 cases occurring in the last thirteen years at the Boston City Hospital (Fig. 464). Roentgenographic examination of the last ten years has discovered many of these cases as well as other instances of fractures difficult to recognize clinically and they are now thought of in differential diagnosis as much as fracture of the shaft.

Cause.—1. Predisposing; syphilis, tuberculosis, rickets and their effect on the epiphysis.

2. Direct blow on the knee or lower thigh accounts for a few cases, as a horse kick or a sudden squeeze with a fall in the opposite direction. Such blows on the shaft above the epiphysis in a young

[1] Loc. cit.
[2] Surg., Gynec. and Obst., xix, No. 2, p. 131.
[3] British Med. Jour., 1912, ii, 860.
[4] Beitr. z. klin. Chir., lvii.
[5] Ann. of Surg., lvi, 869.
[6] Boston City Hosp. Rep., 1913, 16th Series.

child lead to epiphyseal separation, as leg and knee, by means of the gastrocnemius and popliteus, are attached to the lower femoral epiphysis; the same force in adults leads to dislocation of the knee.

3. Cases are caused by indirect violence and the leverage of overextension of the leg. The thigh or leg, one or other, is fixed, and on application of force, the epiphyseal area gives. Most cases are due to the limb being caught in the spokes of a wheel.[1]

Pathology.—The separation may be incomplete or complete, the former term covering the mere starting of the lower fragment out of its position as so frequently seen in epiphyseal injuries of the radius at the wrist. Most of the cartilage usually goes with the distal fragment, only a few shreds remaining on the shaft end. The incomplete variety may have displacement laterally or anteriorly, or a slight rotation. The periosteum is torn but not to any great degree. Hemorrhage into the tissues, secondary hemarthrosis, or effusion into the knee-joint commonly accompany the injury. Complete separations allow displacement in any direction, but the frequent one is that of the lower fragment forward and upward, the shaft fragment downward and backward. The complete type may be complicated by fracture into the joint through the intercondyloid notch, or fracture of the diaphysis above. The second most common displacement is the diaphysis forward and the epiphysis backward into the popliteal space. On account of the violence causing these fractures many may be open. Binney and Lund found 5 open out of 18, with much laceration of the soft parts. Associated conditions are injuries to the vessels and nerves and periosteal stripping for a distance up the shaft. Formerly these injuries were considered so severe that 63 out of 208 cases were amputated at once, with high resultant mortality, but lately better treatment and Roentgen examination give much better results. When the periosteum is stripped up, hemorrhage or callus formation beneath it may cause late pressure on the vessels and nerves, or in cases of extreme displacement the lower end of the diaphysis may primarily burst through the popliteal skin, or later force its way out by pressure necrosis. A case reported by Russell was in a five-year-old boy who was caught in the spokes of a wagon. The leg was found semiflexed, rotated and displaced outward on the thigh, so that it looked like an outward dislocation of the knee-joint. Reduction under anesthesia was attempted but failed, and open operation was done, whereupon it was found that the diaphysis had penetrated into the vastus internus muscle. The periosteum was stripped off the shaft for several inches and had been buttonholed by the shaft, as its lower portion remained attached to the epiphysis. The displacement was corrected and the child allowed to walk eight weeks after the injury.

Involvement of the external popliteal nerve is the common nerve complication resulting in toe-drop. If the nerve is not severed and

[1] Helgemeiner, 171, Russell 4 out of 8, Binney and Lund 7 out of 18.

early reduction is accomplished, this clears up in a few weeks. If the epiphysis is displaced forward, it is drawn upward by the quadriceps extensor. The popliteus and gastrocnemius muscles are attached posteriorly for the most part into the epiphyseal area, although some fibers of the latter are attached to the diaphysis. If the separation is not great these muscles are put on the stretch only, and when replacement is made they tend to hold position, but if the displacement has been extreme and these muscles have been torn from their insertion, they do not act as opponents to the quardiceps and do not help hold the reduction, so that recurrence of the forward dislocation is easier. However, the character of the plane of break is such that its roughness tends to cause firm fixation in many cases, if good reduction is performed. The periosteal stripping or the interposition of capsule or fascia may prevent reduction, especially when the leg is drawn out into extension. Treatment consists in flexion of the leg followed by traction and manipulation in that position, which may result in successful reduction on account of relaxation of the periosteal band.

Symptoms and Diagnosis.—Separation of the lower epiphysis should be borne in mind in all injuries about the knee in patients up to twenty-four years of age. The findings are usually prominence in the patellar region with depression in the thigh just above, bony prominence in the popliteal region from the displaced upper fragment, false point of motion just above the knee-joint, absence of crepitus or very soft crepitus, and shortening. With little swelling or displacement no interference with the blood supply of the leg is expected. If these are great, the leg may be cold and edematous, and no pulsation can be felt in the dorsalis pedis artery. Differentiation from supracondyloid fracture or dislocation of the knee is important. In children supracondyloid fracture is rare, is higher, and the lower fragment is usually displaced backward. Fig. 446 is given as an illustration of supracondyloid fracture just above the closed epiphyseal line. In dislocation the condyles of the femur lose their relation to the head of the tibia and the knee movements are greatly restricted, while this is not so in epiphyseal separation. If the epiphysis is displaced posteriorly, as in rare cases, the differentiation from dislocation backward of the knee is very difficult, and the roentgenogram is necessary.

This separation possesses a greater tendency to recurrence than any other in the body involving the long bones, with the possible exception of the upper end of the humerus. After reduction and fixation, either checking examination for observation of the deformity or condition of the circulation or roentgenograms should be made. As a rule, good functional results follow reduction, and arrest of growth in the bone is not common. There is danger of it, however, and the prognosis should always take that into consideration. Broca[1] found one case of shortening of nearly two inches four years after operative reduction, and Reboul[2] reported a case of lateral deformity when the

[1] Congres de Chir., 1904, xvii, 626.

arrested growth affected one side more than the other, so that genu valgum was present. Screws, plates, nails, or any foreign bodies which pass through epiphyses may cause interference with growth. Other references to cases are made by Bertram,[1] who reports 3 cases, all of the epiphyses being dislocated forward; 2 reduced without and 1 with open operation. Drew[2] reports a case in a boy, aged eight and a half years, on whom open operation was done and a Lane plate applied. Pillet[3] records a case in a child, aged six years, who had trophic changes in the lower extremity from pressure on the nerves. The diaphysis was resected after three months with good functional result.

Treatment.—Because of injury to the cartilage of the epiphysis, early and complete restoration to normal position should be attempted. If there is much cramping of muscles or rigidity, anesthesia should be used at the attempt. In cases of simple complete separation with little displacement, correction by extension and manipulation followed by fixation in a slightly flexed position by a plaster splint is sufficient. If the displacement has been greater, simple extension often fails to effect reduction, but if the leg is flexed to a right angle and traction then made in the longitudinal axis of the thigh aided by pressure on its lower fragment in front, most cases can be reduced. Unfortunately these cases tend to recur so that it is often impossible to put them into extension and a permanent dressing, consequently a plaster cast or swathe in a position of flexion at a right angle is the best treatment, but this should be followed by checking roentgenograms for determining whether the reduction holds. Also assurance must be had that there exists no pressure on the popliteal vessels and nerves. In difficult reductions where open operation is not permitted, the heads of the gastrocnemius may be cut, or a tenotomy of the tendo-Achilles may allow sufficient relaxation for reposition.

If attempt fails through manipulation under anesthesia, or in open cases, operation should be done at once. Painstaking careful adjustment of fragments by leverage and traction without resection of the diaphysis or any part of the epiphysis should be done, perseverance being the best tool to use. If displacement tends to recur, a nail or screw can be driven diagonally through the diaphysis to hold the lower fragment, or if the lower fragment is split, it may be nailed onto the diaphysis by a nail or screw from either the shaft or joint side; if the latter, care must be taken to counter-sink the heads, as foreign bodies sometimes interfere with the growing function. They should be removed after union has taken place, generally in three weeks. For that reason alone, except in rare cases, fixation from the joint side will not often be done. A plaster splint with the leg in very slight flexion is the best permanent dressing, although some prefer a ham splint. After three weeks, passive motion should be started. provided it is painless and the joint is not distended. Under the same

[1] München. med. Wchnschr., March 21, 1911, No. 12.
[2] Roy. Soc. Med., London, Orthop. Section, January 20, 1910.
[3] Soc. de Chir. de Paris, 1911, xxxvii, No. 1.

restriction active use can be started in six to eight weeks. Later, secondary treatment may be necessary for vascular changes or inclusion of nerve in the callus causing toe-drop or trophic changes. If cases are diagnosed early and reduced, or if old joint motion still remains, excision of the knee-joint should never be done, but open operation, tenotomies, and freeing of the fragments, with some freshening of the surfaces, will give reduction. In every case this important epiphysis should be conserved for its future growth.

Fracture of the Condyles and Epicondyles.—Separation of either condyle is usually caused by direct violence, as a squeeze between heavy objects, or a twisting of the leg with the thigh fixed. The

Fig. 465.—Fracture of the external condyle of the femur caused by direct violence with backward displacement. The knee appears dislocated backward.

Fig. 466.—Reduction of this fracture by mechanical extension and direct pressure.

tearing-out force of the bone at the insertion of the knee ligaments also causes lesser fractures. The breaking off of larger fragments is due to direct violence and may be accompanied by much laceration of the skin and soft parts, so that a large percentage of these injuries are open (Figs. 465, 466, 467, 468, and 469). By indirect violence, following a driving upward force of the head of the tibia, a portion of the condyle may be split off or the plane of fracture will be found starting at the intercondyloid notch running obliquely and laterally upward and outward. The split in the lower end of the femur in some of these injuries may extend for several inches up the shaft, and there is a little displacement laterally. When the bulk of the condyle is cracked off by direct violence, its displacement may be quite marked

and is usually backward and upward, or it may be lateral and upward. The lateral ligamentous structures retain their hold above and prevent serious displacement unless they are ruptured. The crucial ligaments may be simultaneously injured. In lateral displacement the knee appears wider.

Joint injury with effusion or blood always is present and may be so marked that the fracture is not suspected until the swelling of the knee has subsided. In lacerations and open wounds the broken portion may be visible and can be replaced in the first dressing. If reduction cannot be maintained, a nail should be driven through the frag-

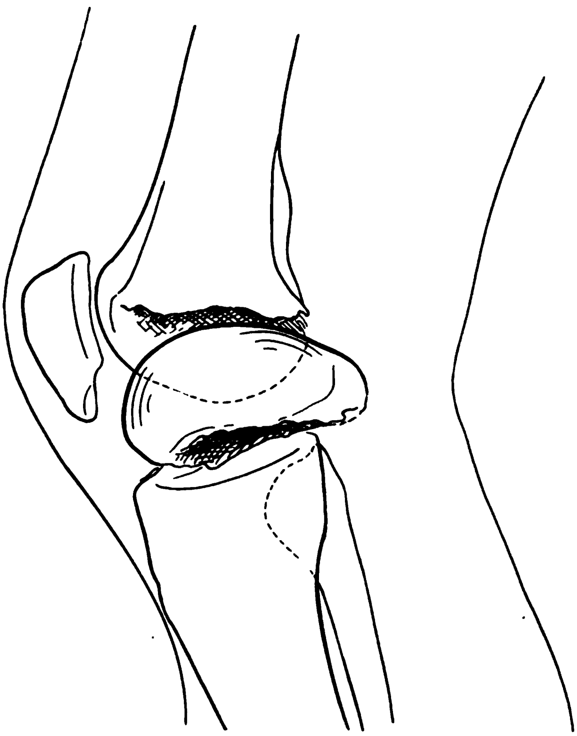


FIG. 467.—Fracture of the internal condyle with complete revolution of the fragment.

ment to hold it in place. Many instances of severe sprain or trauma to the knee which cause these fractures are so quickly followed by swelling and effusion into the knee-joint that the acute symptoms and signs mask the real condition. After rest, aspiration of the joint, or strapping and application of ice, if the function does not improve, very careful examination should be made in attempt to discover any loose bone fragment, crepitus, or a semidislocation of the leg backward or forward. Where the lateral support is weakened on one side of the joint by fracture of the condyle, the leg bones tend to be displaced posteriorly on that side. Rarely the fragment is pushed forward,

but the patellar tendon and the strong lateral ligament restrict displacement in that direction, and as the knee assumes a position of partial flexion, the relaxation of the gastrocnemius and lateral ligament on the posterior aspect favor a posterior displacement more often.

Diagnosis.—The diagnosis is not easy. Careful palpation to test the bony contour in all its aspects, search for a loose fragment or crepitus, or a constant point of tenderness on pressure are needed (Figs. 470 and 471). Added to this is the loss of function and delayed

Fig. 468.—Anteroposterior view of internal condyle fracture with revolution of the fragment.

Fig. 469.—Repair of the condylar fracture. Open operation. No foreign material.

recovery, and the finding of a slight displacement of the knee to one side or other. Very small fragments or sprain fractures arising from tearing out of ligamentous insertion are decided by the roentgenogram after the finding of a persisting small area of tenderness to pressure with ecchymosis. Some of these small fragments are painful, either because of nerve pressure or a low-grade inflammation with attempts at bone development. Others never attempt to unite, as no immobilization has ever been allowed, and they may become sesamoid in character by the constant rubbing of use, their surfaces becoming

smooth until no pain from friction follows. These may sometimes be palpated. It is important to differentiate from enlarged or traumatized sesamoids which are frequently found in the head of the gastrocnemii muscles. Several cases reported in the literature with illustrations, I am sure, are nothing more nor less than insulted sesamoids. Some fragments of appreciable size never unite, become freely movable, and may cause so much pain or disability that their removal is necessary.

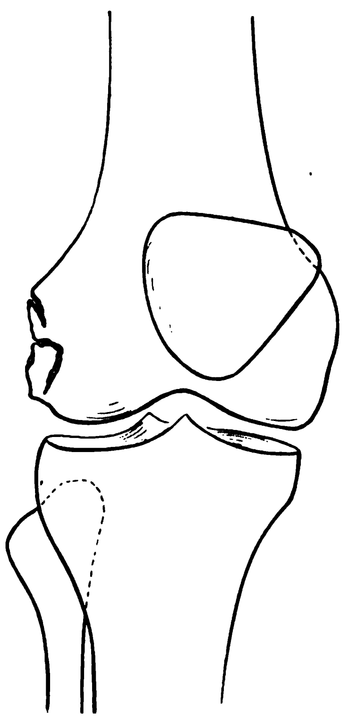


FIG. 470.—Fracture of the external condyle by direct violence.

FIG. 471.—Comminuted fracture of the internal condyle involving the knee-joint.

Treatment.—Treatment of small sprain fracture fragments consists in the strapping of the contused area, or in immobilization of the knee in a moulded splint from thigh to ankle for ten days. If a loose fragment can be palpated and it causes pain or disability, a shorter convalescence can be promised if it is attached with a small nail. Skillern[1] records a case of sprain fracture of the adductor tubercle of the femur caused by a blow on the lower part of the thigh. The skiagram shows clearly separation of the tubercle and a shadow of the

[1] Ann. of Surg., lxvii, 290.

adductor magnus muscle leading to it. Ishimoto and Kaneko[1] have reported 6 cases of fracture of the internal epicondyle, 1 of which was operated on. They reviewed Vogel's 5 cases and believe that they are caused by contraction of the gastrocnemii. The fragments are found to be rough on the inner surface and correspond in other ways to the fragments of sprain fracture. Old cases are sometimes mistaken for myositis ossificans, from which they are hard to differentiate. If there is a complete hiatus between the shadow of the fragment and the femur, we may well suppose that the injury was a fracture. If the shadows merge and extend out into the muscle insertion, it is difficult to say whether a fragment has been fractured off and united again or whether the tearing has caused not fracture, but a deposition of lime salts in the muscle insertion (see chapter on Bone). It is more simple to believe that some lesion, though small, of the bony continuity has occurred, allowing the freedom of osteoblasts and a resulting bony growth.

Fractures of the condyles with displacement should be reduced, as they tend to interfere seriously with joint function. Many can be reduced by means of mechanical extension in a straight line with manipulation for pushing the fragment into position. Illustration is given of such a case which was not diagnosed until it was observed that a suspected knee dislocation, which was supposed to be reduced, seemed to have recurred. Roentgenogram revealed the broken condyle, but as the soft parts were contused and the skin was in no condition for open operation, reduction was attempted by manipulation. With three assistants making traction during anesthesia, nothing could be accomplished; but by mechanical extension, the gastrocnemius fibers pulling on the fragment, I was able to make complete reduction by pushing the fragment down into place, feeling it slip into position with a distinct grinding snap. The leg was put in a plaster splint in extension; no tendency to recur manifested itself, and after six weeks the man had 95 per cent. function in the knee.

Spalding[2] reports a case of separation of the internal condyle of the femur in a man aged forty-seven years. Open operation lasting over an hour was performed; four small bone fragments were removed, and although he nailed the fragment on after pushing it down into position, he failed to get an anatomical reposition. The man had flexion to a right angle and almost complete extension. There was no reproduction of the roentgenogram. Cases which cannot be reduced by mechanical extension and manipulation or which are comminuted should be fixed by nail or screw through a small incision over the condyle concerned. If the mechanical extension is thoroughly tried out first, few cases will demand operation. Postreductive roentgenogram for checking should be made at once.

[1] Am. Jour. Orthop. Surg., ix, 241.
[2] Kentucky Med. Jour., xii, No. 12, p. 380.

CHAPTER XXIII.

DISLOCATIONS OF THE HIP.

PRELIMINARY to the discussion of fracture of the femur the structure of the hip-joint was outlined, and in connection with the central dislocation of the femur the formation of the acetabulum by the fusion of the three pelvic bones was described. When the body lies on a flat surface the pubes are the highest point in front, the hip socket lying midway between the level of the pubes and the floor, looking upward and outward (Fig. 472). In an erect position of the body the sockets look downward and outward, and the other surfaces of the pelvic bones recede from the hip socket to leave it standing out in bold relief, the femur being allowed a corresponding freedom of range of motion at the hip. The acetabulum is deepened and sharpened by a cartilaginous rim and the cotyloid ligament across the cotyloid

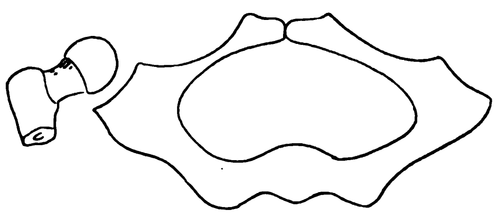


FIG. 472.—Position of the hip sockets, body lying on a flat surface. The pubes highest point in front. Head of femur dislocated forward. Adapted from Allis.

notch, and the femoral head is partly held by the ligamentum teres inserted in the lower part of its spherical surface. Allis believes that the round ligament has little relative power on the head of the joint, because it is not strong enough to prevent dislocation. It is absent in the orang-outang and elephant, but acts rather as an accessory lubricating agent of the joint. At the centre and the inferior margin the acetabular wall is thin; posteriorly and around the peripheral margin it is heavy. The anterior ligament, as we have seen, is the most important one, and its strong fibers passing from the antero-inferior iliac spine to an insertion along the intertrochanteric line on the femur are called the iliotrochanteric or Y-ligament. Bigelow states that this is the strongest ligament in the whole body and that its function is one of checking extreme motions of the hip, the inner band restricting the extension of the femur and the outer band, outward rotation (Fig. 473). Acting in an accessory capacity to the Y-ligament are the ischiofemoral and pubofemoral ligaments, the former supporting the

posterior part of the capsule from the ischium to the femur, and the latter extending from the pubic bone in front of the acetabular margin to the femur above the lesser trochanter.

The head of the femur lies buried less than one-half in the hip socket, being held by atmospheric pressure and the ligaments described. The retentive apparatus of the head holds it securely in the socket without the aid of the capsule, which, if it served this purpose, would always be tense. The capsule really is meant to restrict exaggerated movements, and Allis believes that the head is held in the socket by the cotyloid rim or sucker ligament, basing his conclusion on his own and Weber's experiments. They found that after the entire capsule was cut away it was difficult to draw the head from the socket.

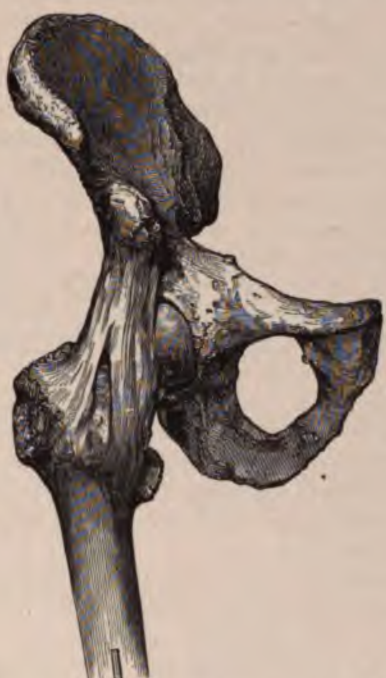


FIG. 473.—The iliofemoral, or Y-ligament. (Bigelow.)

For description of Bryant's triangle and the Roser-Nélaton line which crosses just above the upper margin of the greater trochanter of the femur, together with methods of measuring the leg, the reader is referred to the chapter on Fracture of the Femur. Hip motions of extension and abduction are checked by the ligaments, the iliopsoas muscle, and the other muscles about the joint, and flexion and adduction of the thigh are limited by contact with the soft parts and the restraint of muscles crossing the outer aspect of the hip-joint.

Hip dislocation is relatively uncommon, especially when compared with fracture of the femoral neck diagnosed by the roentgeno-

gram. In my collection of 796 dislocations at the Cook County Hospital I find 39 dislocations of the hip, or approximately 5 per cent., occurred in the period during which there were over a thousand fractures of the femur admitted to the hospital. The statistics of other collections have varied from 1.5 per cent. to 9.75 per cent.[1] Thirteen of the 39 traumatic hip dislocations mentioned were in children under fifteen years of age, a much higher proportion than recorded by most authors. Boehnke[2] made a study of hip luxation in children and believed that they were rare. He collected but 29 cases from the literature and added 1 from the Halle clinic in a five-year-old boy. In Malgaigne's statistics there was 1 case in the first decade and 3 in the second decade of life. Weber gave 3 in the first and 2 in the second; Prahl, 12 in the first and 8 in the second decade out of a total of 41 cases.[3] The youngest case was probably under one year of age. Stimson says the youngest patient was six months;[4] and Boehnke says eleven months in his enumeration of 29 cases. The more recent reports include cases in children of seven years by Carlill,[5] nine years by Rischbieth,[6] eight years by Keenan,[7] and Boehnke's case mentioned previously. Steinke's collection of 10 cases of recent traumatic hip dislocation contained one of a boy aged ten years. Hamilton gives the greatest frequency of traumatic hip luxation as occurring between the ages of fifteen and thirty years. Naturally young adult males are more disposed to the severe traumata which cause hip dislocation. Corner[8] analyzed the statistics on this subject at St. Thomas's Hospital since 1890. He found the luxation in 27 males compared to 5 females. There were more cases in the tenth to twentieth year period, which he calls the heedless decade in those who cross roads. The second greatest period of frequency lay in the decade from forty to fifty among those road-crossers who are less active, but who will not confess it. These facts are interesting, as they concern the number of accidents in modern large cities caused by persons being knocked down by motor vehicles and vans.

Simultaneous traumatic dislocations of both hips have been recorded in 41 cases. These are caused from heavy blows on the lumbar region, falls from a height onto the feet, or crushes from heavy falling bodies. The dislocations may be dissimilar, one side going backward, the other forward, because the patient is twisted or bent over by the trauma. Sladden[9] reported a case in a twenty-four-year-old man who was knocked over by an automobile while riding his bicycle. Both legs were flexed at the hip, and he could not walk. On the right side he had a posterior luxation with two and a half inches' shortening of the leg; on the left side the femoral head lay near the sciatic notch and was one and a half inches short. Both

[1] Agnew, Surg., ii, 89.
[2] Arch. f. klin. Chir., 1913, Bd. cii, 1077.
[3] Inaug. Dis., Centralbl. f. Chir., 1881, p. 57.
[4] Gross's case, reported by Johnson, Philadelphia Med. Times, 1876–7, vii, 5.
[5] Lancet, London, 1914, i, 1288.
[6] Ibid., p. 1111.
[7] Ibid., p. 1359.
[8] Practitioner, London, 1914, xciii, 184.
[9] Lancet, London, 1912, ii, 1013.

sides were reduced, and in three months there was freedom from all disturbance in the hips. Chace[1] reported a case and reviewed the literature of 39 previous cases, 5 of which were poorly reported, the ages varying from eight to sixty-five years. There are 7 cases of double iliac dislocation, but Chace's case is the first double ischiatic reported. The prognosis as to life and function is good. Of 35 cases both sides have been successfully reduced in 26; 3 deaths are recorded.

Open dislocations of the hip are rare. They are caused by severe crushing injuries, or falls from a height. The head of the bone may be forced out in any direction through the soft parts, and the concomitant injuries make the prognosis poor. The mortality in the reported cases has been over 60 per cent., partly from the primary

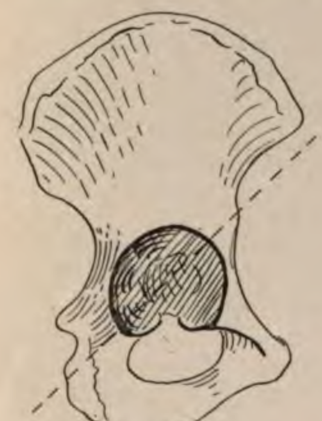


Fig. 474.—Division of hip dislocations by line from the anterior inferior iliac spine through the centre of the acetabulum. Dislocations in front of this line are anterior, back of the line, posterior.

Fig. 475.—Allis's line for division of hip dislocation into outward and inward luxations.

injury and shock, and partly from operative procedure or sepsis. The large bloodvessels are rarely injured. The treatment is first directed toward the shock. When that is combated, reduction with or without the resection of the head is necessary. General anesthesia is used, and the hip-joint is thoroughly drained by through-and-through strips of folded gutta-percha. Whenever possible, the whole bone should be preserved, head excision being reserved for irreducible cases or those which are septic.

Classification and Mechanism.—For most students and practitioners hip dislocations have been a mysterious mass of overclassified injuries. The matter of descriptive nomenclature should be simplified so that general types may be easily recognized, and the diagnosis of positions

[1] New York Med. Jour., 1912, xcv, 171.

of secondary displacement with slight difference should be discarded, so that for practical purposes treatment can be supplied on the basis of a broader understanding. Bigelow's work descriptive of the Y-ligament and its function at the hip-joint offers an opportunity for one to clarify these luxations, and the best classification is one which considers the position of the luxated bone in reference to its relation to the plane of the important ligament. Manipulation and gravity may cause varying secondary displacements, but they are of little practical importance in treatment, and one cannot help agreeing with Cotton, Corner, and others that a division into posterior and anterior luxation is ample (Fig. 474). The plane of division may be made the plane of the Y-ligament, or a line may be drawn from the antero-inferior iliac spine through the centre of the acetabular cavity. When the head is displaced in front of this plane, the luxation is called an anterior luxation; when it is posterior to this plane, it is a posterior luxation (Fig. 475). A few dislocations, the result of extreme violence, which ruptures all ligaments, may move the head in any direction because all restriction of displacement is lost. Central dislocation of the femoral head has been considered under the heading of Pelvic Fracture, which see.

HIP DISLOCATIONS.

1. Posterior—including the dorsal, everted dorsal, and so-called ischiatic types.
2. Anterior—including the pubic, perineal, and obturator types.

General Mechanism of Hip Dislocations.—Autopsy findings and experimental work prove conclusively that in nearly all hip dislocations the capsular tear which permits escape of the head of the bone is below the line drawn from the antero-inferior iliac spine through the centre of the acetabulum. This tear has been caused by leverage action, the lever being one of the first class, and the difference between anterior and posterior dislocation is largely in the anatomical part used as a fulcrum. When the leg is adducted and rotated inward and is subjected to violence, which transmits itself along the axis of the leg, the leg represents the long arm of the lever with the power, the tense iliofemoral ligament is the fulcrum, and the capsular and ligamentum teres resistance at the end of the short arm or head of the bone represents the weight. The capsule gives in its inferior and backward portion, and when the head slips out, displacement becomes posterior to the plane of the Y-ligament. It may assume different positions, aided by further adduction, which carries the head down and backward, or a backward thrust, which carries it backward and upward. Hyperabduction of the femur, on the other hand, causes the greater trochanter to strike against the surface of the ilium as the neck impinges against the acetabular rim and a bony fulcrum is formed. The capsule again tears in its lower portion, lower than in an adduction mechanism, but as the thigh is abducted and

possibly rotated outward, the femoral head is turned forward, and after its escape tends to lie forward of the iliofemoral ligament.

The Y-ligament is not torn in most cases of luxation, and its restraint controls the secondary displacement of the head of the bone. As long as this ligament is intact the dislocation remains within a typical classification, and the position of the limb is characteristic. An intact condition of the ligament also is of great importance in treatment, so that the following simple characteristic positions with an unruptured Y-ligament should be understood.

1. Position of the leg.
   In anterior dislocation the leg is flexed, abducted, and everted.
   In posterior dislocation the leg is flexed, adducted, and inverted.
2. Position of the greater trochanter.
   In anterior dislocation it is displaced backward.
   In posterior dislocation it is displaced forward.
3. Position of the head of the femur.
   In anterior dislocation it is near the pubis and easily felt.
   In posterior dislocation it is in the buttock and difficult to feel.

Direct power which tries to shorten the distance between the adducted knee and the trunk may produce luxation by a direct thrust of the femoral head out backward in spite of all muscular and ligamentous restraint. This is a rare cause of luxation, the excursion of the head being limited by the surrounding tissues. Frequently on account of manipulation or continued force an anterior dislocation may become a posterior one, or *vice versa*, verifying the fact of the capsular tear below the centre of the acetabulum, its extent varying to let the head escape either forward or backward. Powerful force may drive the upper end of the femur in any direction, even through the acetabular wall into the pelvis—central dislocation. The positions assumed are always grotesque and vary widely from the general characteristic positions suggested.

Posterior Dislocations.—The posterior hip luxations are the most frequent, occurring about seven times as often as anterior dislocations. The femoral head is sprung out of the acetabulum, while the leg is in the usual position of adduction, flexion and inward rotation, and after mounting over the posterior acetabular rim, comes to rest at any point above or behind the acetabulum on the dorsum ilii or more toward the ischiatic notch. The weight of the leg or subsequent movements and manipulation may shove the head from a position near the acetabular rim to one farther backward and upward.

Causes.—The usual mechanism of posterior dislocation is found when the leg is in flexion, adduction and inward rotation, and force is applied to the hip-joint from above by heavy weights falling on the body, or from below on the knee or foot when the pelvis is fixed as the patient lies on the ground. The patient might also be caught between large objects when he is upright and supporting a suddenly applied heavy weight with the leg in an abducted and extended position. The luxated hip has probably borne the greater part of the

burden. Exaggerated adduction is often a cause, the thigh being pressed across the opposite thigh by a force. Squeezes between cars and engines, or between boats and docks, with the leg drawn up into this position, have caused luxation. On the cadaver this method usually produces a prompt luxation. Spontaneous or static dorsal dislocation of the hip may occur in patients of any age in the course of a prolonged rest in bed. Ligaments and muscles become atrophic and relaxed, so that sudden turns of the patient by the nurse or a twisting of the leg may produce dislocation. Ridlon[1] states his belief that many so-called cases of congenital hip dislocation are really spontaneous dislocations, and no one can tell just when the femur went out of joint. Many of them do not occur until after the child has started to walk. Ashley[2] reported a case of static dislocation in a seven-year-old girl who had suffered extensive burns and lay prone with her weight on the left elbow and knee for eight months. Shortening of the muscles and the position had caused the femur head to move below the acetabulum onto the lower edge of the pubis. There were no cicatricial contractions about the hip. Reduction was made by manipulation.

Ombrédanne[3] reported a case of voluntary dislocation of the hip in a thirteen-year-old girl who, after a year's experience in throwing the hip out of the socket to amuse herself, was able to repeat the act at will. To cause the dislocation she advanced the knee, rested the toes on the ground, and then suddenly stood erect. The surgeon's hand placed on her hip could feel the head go up back of the joint and then suddenly slip back into the cotyloid cavity. In this case it was believed that there was a congenital aplasia of the posterior part of the acetabulum and capsule which had been further weakened by the acquired stretching of the muscles. Héully[4] has seen a similar case, and Bigelow[5] mentioned seeing 3 cases, one in an adult soldier. Hamilton also collected 3 cases.

Spontaneous dislocation after typhoid fever does not belong in the traumatic class. The luxation is associated with effusion into the joint and should be classed with the luxations following the arthritides of acute infectious diseases like scarlatina, influenza, etc. An acute process has weakened or destroyed the capsule and ligaments. A class of luxations is found following paralyses which involve groups of muscles about the hip. Active muscles overcome the normal joint resistance by pulling eccentrically to the acetabulum and cause luxation of the head forward when the abductors are intact, and upward and backward when the adductors are active.

Pathology.—The capsular tear is usually in the lower portion posteriorly, and the size of the opening varies. In the regular forms it

[1] Am. Jour. Orthop. Surg., 1914, xii, 673.
[2] New York Med. Jour., 1915, ci, 608.
[3] Rev. d'Orthop., 1912, 3 S., iii, 396.
[4] Rev. de Chir., June, 1911, obs. xxvi, 771.
[5] The Hip, p. 112.

is at least large enough to let the head escape, and the Y-ligament is not injured. In the irregular forms all the ligaments, including the iliofemoral, are torn away. This condition has been proved by autopsies on patients dying within a few days after hip luxation, or by first-hand inspection by arthrotomy on fresh dislocations. The ligamentum teres may be ruptured in its continuity or more frequently is torn away at the femoral head. As the head of the femur is luxated out of the socket, it usually comes below the obturator internus muscle, and in the subsequent displacement backward this muscle is pulled behind, so that it lies between the femoral neck and the acetabulum. The pyriformis, obturator externus, gemelli, and quadratus femoris muscles are frequently torn, but any group of them may be spared with increased laceration of their neighbors. They lie in close contact with the capsule and may be torn by the original trauma of luxation or by the subsequent pressure of the neck and head of the bone passing to its ultimate displacement. The glutei are not often lacerated, but the quadratus femoris was found by Dollinger torn in 11 out of 12 cases.

The acetabular edge or the pelvis may be fractured. In 7 cases Dollinger found 2 fractures of the acetabulum and 2 of the pelvis. The head of the femur may also be fractured. Crile[1] reported a case involving the posterior portion of the head and acetabular rim.

Position of the Femoral Head.—Like all ball-and-socket joints, the head of the displaced bone may lie near the socket rim in the hip, or at as great a distance as surrounding structures will permit. The usual position is that which has been described as "low dorsal" when head is between the ischiatic notch and the acetabulum (Fig. 476). When it moves higher up posteriorly and comes to lie on the dorsum ilii it is called "high dorsal." In the low form the head has been found at the base of the ischial spine. "Everted dorsal" is a rare secondary position, described by Bigelow, in which the thigh is pressed back, abducted and rotated outward after the head has escaped from the capsule. This position puts so much stress on the outer fibers of the iliofemoral ligament that they rupture, and the intact remaining portion pulls the femoral head forward over the ilium toward the anterior inferior spine. This type has also been termed the "supra-cotyloid."

In the high dorsal dislocations, which are seldom seen, the head lies more backward and upward than it does distinctly upward. Malgaigne found in 5 cases out of 11 examined that the head had risen only to the level of a line from the antero-inferior iliac spine to the upper margin of the great sciatic notch and in the others not more than an inch above the line in any case.

Dollinger[2] reported on 22 cases of hip dislocation, 4 of which were reduced by manipulation after four, six, eight, and nine weeks respectively. Although he made attempts to reduce the others by bloodless

[1] Ann. of Surg., May, 1891.

[2] Ergebnisse der Chir., iii.

methods he had no other successes, and subsequent arthrotomy demonstrated the reasons. After violent manipulative efforts the femoral heads showed abrasions and contusions. The permanent changes about the luxation were divided into four groups:

1. There were changes in the acetabulum. Every case but one was filled with connective tissue proliferated from the capsular shreds and fat, all grown into a mass, which had to be cut out piece by piece to expose the acetabulum. Beneath, the cartilage was intact except in two long-standing cases.

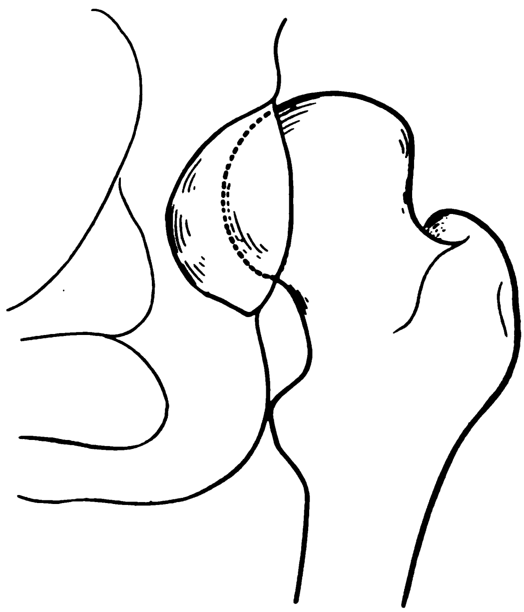


Fig. 476.—Usual posterior hip dislocation. Head back of the acetabulum, trochanter elevated.

2. Changes in the femoral head were few except in one case of long standing—nine months—in which there was a gnawed appearance of the bone. The head was uniformly surrounded by the proliferated periosteum in its new position, and the neck was adherent to the pelvis by thick connective tissue.

3. Changes in the capsule were very marked. The capsule could not be identified nor dissected free from the cicatricial mass about the head, and no site of rupture could be identified.

4. Changes in the muscles were those of shortening and disuse, although, as previously stated, the quadratus femoris was torn in every case but one. The shortening of the piriformis, obturator internus, and gemelli were amenable to stretching by traction with a block and pulley.

Symptoms.—The patient is, as a rule, unable to rise to a standing position. He lies on the ground, holding the dislocated leg rigidly in a position of flexion, adduction, and inward rotation, so that the foot rests on the dorsum of the opposite foot, or the knee lies resting on the front of the opposite knee a few inches above the joint (Fig.

Fig. 477.—Dorsal dislocation of the hip. (Stimson.)

477). The position of the head in luxation without fracture has been considered to be the same as the position of the internal condyle of the femur inasmuch as they point in the same direction. The surgeon is assisted by this fact in determining the direction of the axis of the neck in dislocation, or he may use the axis of the foot as a guide,

taking into consideration that it points at right angles to the condyle. Active movements are not possible. Passively the injured thigh can be flexed and probably slightly more adducted, but abduction and extension are not possible, and the attempts cause pain. In some cases the leg can be brought down flat into a line with the opposite leg by flexion of the spine, the position of lordosis being seen or felt by the hand slipped under the back at the pelvic rim. Examination of the hip region shows that the greater trochanter of the femur has risen above Nélaton's line, and the gluteal fold on the injured side is less pronounced and is higher than on the sound side. Palpation in very thin subjects may permit the surgeon to feel vaguely the head move beneath the gluteal mass, but where there is much subcutaneous fat, it is impossible to palpate the head accurately. In front of the joint the normal fulness caused by the presence of the head below Poupart's ligament is lacking, and a finger can be depressed deeply into the tissues. The difference from the normal side is striking, and the findings are also the opposite of fracture of the femoral neck, in which the depressibility of the tissues in front of the joint is diminished.

The degree of flexion and inversion of the leg varies with the displacement of the head away from the acetabular rim and with the tension of the Y-ligament fibers which anchor the intertrochanteric line to the anterior inferior iliac spine. When the head is in a position near the ischiatic notch and the ligament is intact, the leg must lie in marked inversion. Posterior dislocation on the ilium is not accompanied by a great amount of inversion, because the tension of the ligament is somewhat relaxed, and in the everted dorsal luxation the ligament being ruptured, inversion no longer exists but gives way to eversion.

Adduction and flexion also depend on the integrity of the iliofemoral ligament and the position of the head. A high posterior position of the head will let the leg extend downward until there is but slight flexion compared to the opposite side. Low positions of the head just back of the lower acetabular edge will bring the leg into greatest flexion and adduction. Muscular action may influence the positions of flexion and adduction somewhat, especially if the dislocated head is hooked under the external rotators, which remain intact and hold the head in position, a condition which can be maintained only by flexion and adduction of the leg.

Shortening is more apparent than real, the true anatomical length being disguised by the soft parts covering the bone and the clinical obstacles to critical measurement. In the chapter on Fracture of the Femur the methods of measuring the leg are given, and attention is directed to the necessity of placing the limbs in a corresponding position of flexion on the trunk and at an equal angle with the long axis of the body drawn perpendicular to the transverse pelvic axis. The flexed position of hip luxation is rigidly fixed, and the leg cannot be brought into a position corresponding to the uninjured leg, which also

cannot be carried into the flexed and adducted position on account of interference between the two legs. Length measurements are therefore unreliable and fortunately are not necessary for diagnosis. Apparent shortening may be two or three inches, whereas real shortening probably does not amount to more than an inch. The distance from the anterior superior iliac spine to the tip of the greater trochanter is lessened in posterior dislocations, usually not to exceed one inch.

Everted dorsal dislocation differs from the usual posterior luxation, because the leg is everted, instead of lying in inversion, as do all other posterior displacements. As we have seen, this position is caused by the rupture of the outer fibers of the ligament, and the head is drawn upward by the remaining intact portion above the acetabulum. Bigelow first described this type, the leg lying in eversion and outward rotation, with shortening of two inches or more. The head of the femur may be drawn upward to lie between the two anterior iliac spines. Violent efforts at reduction of posterior luxations may rupture the Y-ligament, and an everted dorsal luxation results. Lente[1] recorded a case of this kind which followed traction and outward rotation. Van Buren Symes, Kocher, and Stimson have reported cases which were recognized as everted dorsal dislocations. The head does not lie on the broad iliac surface but is supracotyloid, and lies far forward, so that there is more or less eversion instead of inversion of the limb. Extension is not interfered with; so there is no flexion of the thigh, and the leg lies in an extended position, its longitudinal axis but slightly disturbed. There is free mobility in the hip, and the leg is usually rotated outward, with shortening, which leads the surgeon to expect fracture of the femoral neck.

Allis[2] reported a case of a man who was leading a horse which fell on him after rearing on the ice. His thigh was abducted and slightly flexed at both hip and knee, the foot being turned outward. Reduction was accomplished by the surgeon fastening the pelvis to the floor, flexing the leg on the thigh and the thigh on the pelvis, and following with traction upward until the femoral head reached the socket. Efforts to reproduce the condition of everted dorsal dislocation were made on a cadaver strapped to the table. The femur was flexed to a right angle with the pelvis, the leg being at right angles to the thigh, the knee was steadied by the operator's hand, and the femur was rotated by his seizing the ankle and turning it inward toward the pubis like a wheel spoke. This rotation ruptured the capsule, and the head fell out of the socket into eversion, but fracture of the femur was produced experimentally as often as dislocation. The position of eversion often misleads the surgeon into a diagnosis of fracture of the femoral neck. König believes that all everted dorsal dislocations result from a breaking away of the posterior wall of the acetabulum. Roberts[3] cited a case of hip injury in a woman, aged twenty-six years, who had been confined to bed for many months on account of her

[1] New York Jour. Med., 1850, p. 314. [2] Tr. Am. Surg. Assn., xxix, 94.
[3] Ibid., 96.

disability. The legs were parallel to each other, the right hip was rigid, the leg was shortened, and the foot everted. Upward displacement of the trochanter measured one and a half inches, and when the leg was abducted, the buttock was flattened, but there was no kyphosis. All motions were greatly limited, and a diagnosis of old fracture of the neck and hysteria was made. A study of the roentgenogram, however, showed a dorsal dislocation with eversion, and it was decided that the best treatment was to excise the head rather than to attempt to replace it in the acetabulum by open operation. This procedure was carried out. The head was found resting in a socket-like depression deepened by the inflammatory thickening of the surrounding soft parts. Mr. Stiles, of Edinburgh, discussing this treatment, stated that it was better to remove the whole neck, because it would slip up afterward and an unstable joint would result. The whole neck should be removed, and the trochanter should be rounded off and placed in the acetabulum in abduction to give a stiff but stable hip-joint. He mentioned two cases so treated by him. The same advice as that given under old fractures of the femoral neck may be given here, namely, a bony ankylosis may be obtained either to the acetabulum or to the ilium when the trochanter cannot be brought into the acetabulum.

Everted anterior dislocation of the femur must also be differentiated by failure to feel the head anteriorly. Fracture is eliminated by the rigidity of the leg in the everted position, the pain caused by attempts to invert the dislocation, and the recognition of an unbroken continuity of the neck verified by the communication of shaft movements to the head, which can be felt by the fingers placed over it above the acetabulum. Flexion of the thigh with inward rotation and adduction may bring the head into the customary posterior position, and complete reduction can be accomplished by further flexion and rotation with traction or pressure downward. The condition of rupture of the outer fibers of the Y-ligament may exist without the head assuming the position of everted dorsal dislocation. These cases may be recognized in the course of the usual manipulative reduction (see Treatment). When abduction fails to cause the head to slip into the acetabulum, the fulcrum of the Y-ligament fibers being lost, reduction is then accomplished by traction forward on the flexed and adducted thigh.

Treatment.—Until Bigelow's epoch-making work on the causes and pathology of hip luxations was adopted by surgeons all over the world, reduction by manipulation had gained but little recognition. Manipulation had been known and used as a means of reduction from the time of Hippocrates, and in 1670 Wiseman advocated forcing the knee up onto the belly and pressing the head into the acetabulum.[1] Boulton, Turner, Anderson, and Physick also reported manipulative reductions prior to the teaching of Nathan Smith in 1815. These men recognized muscle intervention as a greater obstacle than liga-

[1] Quoted by Hamilton, Fractures and Dislocations, 1880, 6th American ed.

mentous pull. Reid,[1] in 1851, advocated manipulation, and Gunn,[2] Moore,[3] and others, after experiments on the cadaver, concluded that the ligament and capsule were the main obstacles to reduction by direct traction. Hamilton himself[4] reported 41 cases of hip luxation, 28 of which were reduced by manipulation on the first trial, 7 on the second, 4 on the third, and 2 on the seventh. Attempts at reduction by direct traction from strong multiple pulleys continued to be the general practice, however, with the leg in complete extension. Often the reduction did not succeed and when the head was dragged into the acetabulum, it was at the expense of rupture of the Y-ligament. After Bigelow's publication in 1869 (*The Hip*), and his later contribution,[5] the importance of the iliofemoral ligament was accepted, and reduction by manipulation became the recognized method in all regular luxations. In 1896 Allis[6] made refining changes in the manipulations with a view to decreasing the force used and thus eliminating tears in the capsule and soft parts and to taking advantage of the Y-ligament as a fulcrum.

From the previous description it is understood that the Y-ligament is the main obstacle to replacement of the head in the acetabulum when the leg is extended, and it is this intact ligament which holds the femur in a position of flexion, internal rotation, and adduction. The first step in reduction of posterior luxation must necessarily be flexion for relaxation of the ligament. Besides relaxing the ligament, flexion lowers the head of the femur along the posterior rim of the acetabulum, and it approaches nearer the tear of exit in the capsule. The position of adduction and rotation inward of the limb is maintained in this maneuver and tends to draw the head somewhat from the iliac wall out to the acetabular rim. Muscle interposition, especially that of the obturator internus, is also removed by this position. The three principal methods of reduction are (1) Allis's direct method; (2) Bigelow's circumduction, and (3) gravity method of Stimson.

(1) *Allis's Method.*—The pelvis can be fixed to the floor by means of bandages or straps passed through three staples. One staple is placed on each side of the iliac crest, and the third is placed between the legs in front of the perineum. If the means for this fixation are not at hand, Ridlon's method of steadying the pelvis may be used. That is accomplished by the operator's flexing the uninjured thigh on to the pelvis and against the trunk and strapping it in that position, so that the assistant has something firm to grasp and can hold the pelvis easily.

The thigh is flexed in its position of inward rotation and adduction; the Y-ligament is relaxed; the head descends and approaches the rent in the capsule. The second step is for the operator to lift the thigh

[1] Buffalo Med. Jour., August, 1851, vii, 129.
[2] New York Jour. Med., September, 1848, p. 268.
[3] Ibid., November, 1853, p. 423.
[4] Buffalo Med. Jour., November, 1857, and February, March, June, 1859.
[5] Lancet, 1878, i, 861.
[6] Gross Prize Essay, Philadelphia.

forward with both arms, the pelvis being held fixed by an assistant, or by the operator's foot placed across the iliac spine. This maneuver is generally sufficient to produce reduction, but if there is any resistance felt in the lifting and the head does not slip into the acetabulum, the thigh is adducted more to relax the capsule and is again lifted. If obstacles still persist, slight movement of outward rotation may remove them if they are the short muscles and sciatic nerve, after which the head can be lifted into the joint. Very little force should be used, because this method aims to avoid further laceration of the articular structures and is not dangerous.

After the head is in the acetabulum or over the edge of the cavity the leg is allowed to extend fully on the flat surface on which the patient lies. It must not be forcibly extended. High posterior luxation in which the femoral head may have escaped by a tear higher in the capsule does not require so much flexion of the thigh for bringing of the head near the capsular opening. Consequently the traction of lifting is applied before much flexion is made, or with the leg in the position found in the displacement.

(2) *Bigelow's Method: Circumduction.*—The original description contained instructions for the use of general anesthesia. By flexion of the thigh on the abdomen the same step described in Allis's method was used, namely: an exaggeration of the adduction and inward rotation, already existing, to relax the iliofemoral ligament. The femoral head was then lifted or jerked upward into position. External rotation must be avoided in the first motions, as they may rupture the Y-ligament and bring the head farther upward and forward or downward to the obturator foramen, if there is flexion, abduction, and traction. Failure to reduce by this manipulation necessitated outward rotatory movements, the circumduction being performed *simultaneously with the forcible lifting,* and followed by extension. The circumduction made use of the intact Y-ligament as a fulcrum to lever the head into the acetabulum after the preceding movements brought it to the edge of the acetabulum. Bigelow's second paper[1] gives the following brief description of reduction:

"(1) Flex and forcibly lift. If this fails,

"(2) Flex and lift while abducting. If this fails, it will be found that the rent in the capsule has been so enlarged that the first method may now prove successful."

In making this reduction the surgeon must bear in mind that the result is obtained by the force of traction or lifting, and that the circumduction is secondary and used only to remove obstacles from the path of the head. These rotatory motions must be limited, and the abduction must not be forced lest the Y-ligament be torn and possibly some other type of dislocation be produced. During the course of the rotation the traction on the thigh must be steadily maintained. Relaxation of the traction lets the head fall back, pulled

[1] Lancet, 1878.

by gravity and the muscles about the joint, so that a new position is established in the surrounding tissues and the head is not in a position near the acetabular rim, where the surgeon intends it to be when outward rotation levers it into the acetabulum just prior to reduction.

(3) *Stimson's Gravity Method.*—The gravity method[1] aims at reduction on the same general principle as the two previously described, but places the anesthetized patient face downward with both legs hanging over the end of the table (see Fig. 478). The sound limb is held horizontally by an assistant, and the surgeon grasps the injured

FIG. 478.—Gravity method of reduction of dorsal dislocation of the hip. (Stimson.)

leg at the ankle, flexing the knee to a right angle and holding the leg in slight adduction. Gravity exerts sufficient force to pull the femoral head gradually into place after muscle relaxation occurs. A sand-bag and pressure downward back of the knee may be used to aid traction. This position simply reverses the lifting traction of the direct method.

Anterior Dislocations.—In Steinke's collection of 10 cases of hip dislocations at the Episcopal Hospital, Philadelphia, in ten years, there were 2 anterior, 1 pubic, 1 thyroid, and 8 posterior luxations.

[1] Stimson, New York Med. Jour., August 3, 1889.

The anterior luxations are less frequent than the posterior, and may be classified into the following varieties:

(1) Pubic luxations, including the suprapubic and subspinous and the luxations directly upward.

(2) Obturator or thyroid luxations, the most frequent type.

(3) Perineal.

Pubic Luxations.—*Causes.*—In the general remarks on the mechanism of hip dislocations it is stated that the position of abduction causes the neck to impinge against the rim of the acetabulum and the greater trochanter of the femur to strike against the ilium. The head is thereby levered out of the joint by a rupture in the lower anterior portion of the capsule, because the Y-ligament retains the upper end of the femur in its relation to the ilium. The causes are falls on the leg, which is abducted and hyperextended, and forcible hyperextension of the trunk on the legs, which remain fixed. A man may make a misstep going down a flight of stairs or in walking step into a hole and suddenly throw his body backward to save himself from a fall while the thigh is abducted and extended. Sudden application of trauma on the back with the legs spread apart may likewise produce a pubic dislocation. Another cause is that found when a man is riding between two cars, sitting on the sill of one with his legs elevated on the sill of the other. A sudden jerk of taking up slack in the train, or the application of brakes, shortens the distance between the cars and forces the leg upward against the trunk, causing dislocation. The luxation is not the result of direct violence pushing the femur upward out of the socket while the leg is extended directly forward, but results after a turning of the trunk has been unconsciously performed to allow for flexion of the leg. The pelvis twists to one side on the fixed leg which does not flex by knee action, and the leg is placed in a position of abduction and probable outward rotation, so that an anterior dislocation follows. I saw at Mercy Hospital a case of similar origin in the service of Dr. Pierce, resulting in posterior luxation. A fireman stood on the engine deck, his back to the cab, his thigh flexed, and his knee braced against the front of the water tank, which was just far enough away to permit the assumption of that position. Switch duty was being performed by the engine, and while the fireman was standing thus the engine made a cross over which slightly approximated the tank to the cab surface and irresistibly pushed the flexed femur in slight adduction out of the socket posteriorly. In this instance the trunk was fixed and could not rotate to bring the leg into abduction, because the man's back rested squarely against the flat surface of the cab.

Pathology.—The capsule is ruptured in the lower anterior portion, and the head escapes in front of the joint and comes to rest on the superior ramus of the pubis, the extent of its excursion toward the symphysis varying with the amount of force and the stretching or laceration of the ligaments. Tearing of the Y-ligament is unusual, and the ligamentum teres is generally pulled off at the insertion into

the femoral head. The head of the bone pushes the muscles and vessels in front of it and rarely injures them. The external rotators of the hip are drawn tightly over the acetabulum. Two cases of injury of the femoral vein have been reported in pubic luxations. The sciatic nerve is entirely removed from the possibility of injury, but the anterior crural nerve may be pressed upon or stretched so that anesthesia develops in its distribution. Open dislocation has been reported[1] either from protrusion of the head by pressure from within outward, or by laceration of the soft parts in front of the joint from the hyperextension. In a very few instances the head of the bone has been driven far upward into the groin and in one case[2] complicated by fracture of the femur in reduction attempts, the head was found at autopsy in a position between the psoas and rectus muscles above the iliopectineal eminence. Extreme anterior positions may cause vessel rupture, and that possibility must be considered in examination of the forward luxations.

Symptoms.—When the head lies in an anterior position on the iliopectineal ridge, it can be palpated on the groin below Poupart's ligament, and the femoral artery lies stretched over it or on the inner side. Injury of the femoral vessels is rare because of their position anterior to the joint, which causes them to be lifted up by the tense muscles beneath at the instant of dislocation. The vessels are approached by the head in anterior dislocations alone, and to cause that displacement the leg must be flexed and abducted, a position which stretches the muscles forming the floor for the vessels with the previously mentioned result (Fig. 479). The leg is abducted slightly and the foot is turned outward. The amount of abduction of the upper part of the limb depends on the amount of displacement of the head inward along the pubic ramus; the farther inward it lies, the greater the abduction of the thigh. Attempts to adduct the leg meet with the firm resistance offered by the intact Y-ligament, which holds the femur to the inferior iliac spine, and by the pressing of the head against the pubic ramus. Abduction and flexion are possible, and the patient may be able to walk as the leg is generally in a position of full extension. The whole leg appears lengthened, and there is flattening over the trochanter, which has lost its normal prominence. Rarely the head is pushed up over the edge of the pelvis beneath Poupart's ligament or bursts through it. Wide displacement means complete rupture of the ligament and an unstable position.

Treatment.—Traction exerted on the leg in a position of abduction and extension followed by adduction and pressure against the head has resulted in successful reduction of pubic dislocations. But since it may cause injury to the vessels, a manipulation has been worked out which relaxes the Y-ligament and psoas muscle and does not put too much strain on the intact posterior portion of the capsule, which is used as a fulcrum. When the head rests on the pubic ramus and

[1] Cheever, Stimson, Goldsmith.
[2] Verneuil, Bull. Soc. de Chir., Paris, 1870, xi, 145.

the thigh is flexed, the Y-ligament relaxes, but the head of the bone instead of descending on the surface of the pubic ramus may be pushed farther up under Poupart's ligament, being held by the posterior portion of the capsule. To overcome this obstacle to reduction and to avoid damage the operator draws the limb down by traction in its position of abduction until the head is beginning to descend from its pubic position and he knows that the posterior portion of the capsule is tense. Then he makes direct pressure downward on the head of the femur to hold it in the position gained by traction while partly flexing the thigh. This maneuver will often cause the head to slip into the socket. If it does not, the pressure over the head is increased, and the thigh is rotated *inward* until reduction follows.

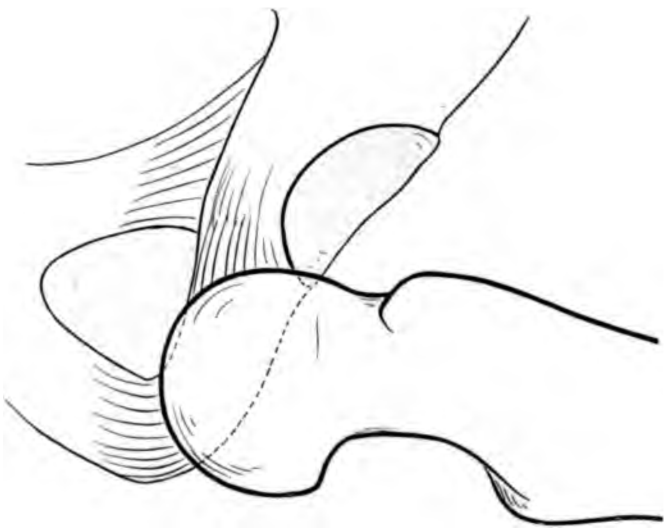


FIG. 479.—Pubic dislocation. Note the head in front of the acetabulum on the pubic ramus and the abducted position of the leg.

Subspinous luxation and luxation directly upward are two exaggerated types of anterior dislocation. The femoral head passes from a suprapubic position upward and backward until it lies above the acetabulum, and the term supracotyloid or subspinous is applied to this secondary position below the antero-inferior iliac spine. Two distinct groups of subspinous luxation may be anticipated—one, a secondary position following anterior luxation, and the other, a primary displacement from direct upward forcing of the femoral head. Stimson[1] reported a case of direct upward dislocation caused by a man falling beneath a heavy case. The thigh was extended and slightly abducted and the foot markedly everted. The skin over the upper thigh had been torn by overstretching, and the head of the femur lay an inch directly below the anterior inferior iliac spine.

[1] Ann. of Surg., December, 1892.

In either group wide laceration of the capsular ligament must be present, and the upper fibers of the Y-ligament are also torn. Autopsies have been performed in a few instances of this luxation and these findings confirmed. There is eversion of the foot, some shortening of the leg, the head is palpable below the spine, and adduction and internal rotation are lost. Abduction and flexion are possible but painful, and the luxation may be compared to the everted dorsal in its clinical findings and pathology.

Treatment adopting the rule of attempting reduction over the path which caused the luxation by placing the limb in the position it assumed at the time of injury, does not apply well here on account of the extensive laceration about the hip-joint. Reduction is accomplished by traction on the thigh in a position of partial flexion, an assistant making direct pressure downward and backward on the head of the femur during the traction.

Obturator, or Thyroid Dislocations.—Luxations into the thyroid depression are the most common of anterior displacements. The basis for division of hip luxations into anterior and posterior has been previously given, based on the excursion of the head after it leaves the usual rent in the inferior portion of the capsule. A position of abduction and flexion of the thigh at the time of luxation causes the head to pass forward and downward toward the obturator opening.

The causes are falls with the legs spread apart or heavy weights pressing against the lumbar spine when the thigh is abducted and flexed.

Pathology.—The capsular tear need not differ much from that found in posterior dislocation. It occurs on the inner lower anterior side and is near the acetabular insertion. The Y-ligament is relaxed; the head passes forward and inward and rests in the obturator foramen. The ligamentum teres has been found completely torn off or simply stretched without laceration. Muscle laceration and complications are similar to those of posterior luxations (see Fig. 480).

Symptoms.—The untorn Y-ligament holds the femur and thigh abducted, everted, and partly flexed. There is some apparent lengthening of the injured limb if both are brought into a line of complete extension, because the pelvis tilts upward to accommodate the forced extension of the thigh. Marked restraint in adduction and extension is caused by the impingement of the great trochanter held by the Y-ligament on the lower acetabular border, and not so much by the pressure of the head in the obturator foramen. The greater trochanter is concealed on the outer surface of the hip, which is flattened and relaxed. There exists a depression between the ilium and femur from relaxation of the fascia and muscles, favored by the inward displacement of the trochanter. The head of the bone can sometimes be palpated by deep pressure of the examining finger down toward the thyroid depression, but the trochanter is hidden even when rotatory movements attempt to locate it. If the displacement is marked, the head slips deep down into the obturator foramen, and the trochanter slides into the acetabulum (Fig. 481).

Everted thyroid luxation is a rare form resulting from further rotation of the femur outward, which brings the head into more promi-

FIG. 480.—Obturator dislocation. (Bigelow.)

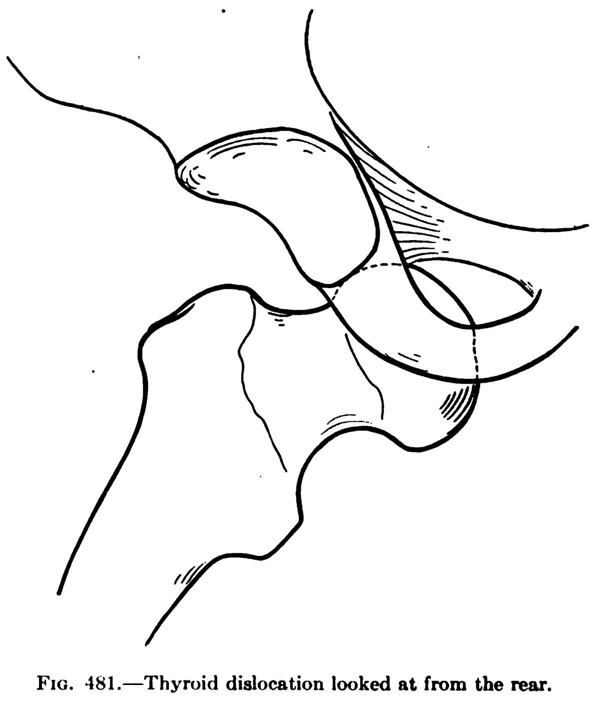


FIG. 481.—Thyroid dislocation looked at from the rear.

nence anteriorly and carries the trochanter farther inward until it rests in the thyroid depression. The rotation causes the Y-ligament

to become twisted around the neck of the bone. Here the trochanter lies against the inferior surface of the horizontal ramus of the pubis. The everted anterior type may also be a sequence of pubic dislocation. When it follows a luxation originally thyroid, the femoral head points outward, the trochanter is pressed in against the thyroid depression, the toes point backward, and the internal malleolus is turned completely outward.

An additional type of dislocation which lies just below the acetabular margin midway between the thyroid depression and the ischium has been called infracotyloid dislocation. In 1905 Niederle collected 20 cases of this type.[1] The condition probably presents the early stage of many hip luxations, when the head of the bone has emerged from the inferior portion of the capsule and its further excursion into a position anterior or posterior to the line drawn from the antero-inferior iliac spine has been checked. Continued action of the causing violence, with the thigh brought into a position of adduction and rotation inward, will lead to an ordinary posterior luxation, and if outward rotation and abduction of the thigh follow, a thyroid dislocation is expected. The cause of infracotyloid dislocation is the same as dorsal luxation, the head lies midway between the two points mentioned, and the intact Y-ligament holds the hip slightly flexed, either in eversion or inversion. Manipulations may extend the capsular and muscular tear and convert the condition into a true anterior or posterior luxation.

Treatment.—Reduction may be accomplished by the surgeon bringing the head up to the capsule opening and lifting or pulling it into the socket. This result is accomplished by his flexing the thigh and rotating it still farther outward to relax all the joint structures. He then makes traction in the direction of the long axis of the leg to bring the head nearer the socket, the knee being flexed, and follows this by inward rotation and extension of the leg to a normal position as reduction ensues. If this fails, he may change the last step to an outward rotation or a rocking of the head in and out, using the outer branch of the Y-ligament as a fulcrum to lever the head upward into the socket. A towel or wide band applied around the upper part of the thigh may be used for angular traction outward in connection with the traction made by the operator in the long axis of the leg. An assistant's fingers pressing on the head may be substituted for the accessory lateral traction, the fingers acting as a fulcrum on which the bone head is levered back into the socket. Bigelow advised flexion and adduction of the thigh to convert the dislocation into a dorsal position and subsequent reduction used by the means prescribed for that position. This entails further and unnecessary capsular laceration and will not be needed unless other methods fail entirely.

In all the described movements too much flexion must be avoided, as that pushes the head farther into the thyroid depression by increas-

[1] Centralbl. f. Chir., 1905, p. 31.

ing the tension of the Y-ligament. Slight forward traction is the force needed to lift the head near the capsular tear, rather than any backward push, which may easily convert the luxation into a dorsal position. For everted thyroid luxation, when the head has turned outward and the trochanter lies on the thyroid depression, the limb must be rotated gently inward that the Y-ligament may be unwound from the neck of the bone until a position of ordinary thyroid or pubic luxation is reached, after which the method of reduction described for that position may be employed.

Perineal Luxations.—But few instances of this type of anterior hip dislocation have been reported. The causes of perineal luxations are probably the same as those of the thyroid dislocations, with the employment of greater force in extreme abduction. The head is forced out of the capsule on the anterior surface and is carried well inward and forward of the obturator depression until it lies in the perineum.

The pathology includes a wide tearing of the anterior and lower portion of the capsule and probably also of the Y-ligament. The head has been pushed inward and forward and may press upon the urethra or rupture the perineal skin.

The thigh is flexed and usually extremely abducted beyond a point to which it is possible to abduct the sound limb. Palpation of the perineum discovers the femoral head at a slight distance from the midperineal line anterior to the anus. The leg may be in inversion or eversion, or the position of the luxation may be unstable on account of the extensive ligamentous laceration. Attempts at extension and adduction of the leg cause pain and are opposed, but some flexion and rotation of the thigh are possible.

Reduction is made by direct traction in the long axis of the thigh in the extreme abducted position, aided by pressure on the head of the bone backward toward the joint socket. A position of thyroid dislocation may result and flexion of the thigh with outward traction causes reduction. A towel slung around the upper part of the thigh may make extra traction outward on the upper part of the femur and assist in reduction. Sometimes, but rarely, rocking movements are needed to push the head back through lacerated capsule and ligament.

Complication of Hip Dislocation.—Complications are unusual and have been mentioned under the different types of luxation discussed. Muscle rupture is a likely occurrence in any of the exaggerated forms of luxation or in violent and unwise attempts at reduction. High posterior luxations may tear the glutei, and anterior luxations into the thyroid depression or onto the pubis may rupture the adductors of the hip and the pyriformis. Small muscle tears are expected in any luxation, and no special treatment is indicated unless the torn muscle acts as an obstacle to reduction. In exaggerated luxations a longer period of immobilization of the joint is demanded for the sake of capsular repair, and the muscle injury is repaired during

this period. Healing by scar formation probably leads to a slight unrecognized difference in function later.

Rupture of the femoral vessels is very rare. It occurs only in anterior and open luxation. The prognosis is grave.

The sciatic nerve is injured only in posterior dislocations. It may be caught against the neck of the femur in the dislocation primarily, or it may be picked up and stretched over the bone by attempts at reduction. A few instances of rupture and entanglement of the nerve have been seen at operation and autopsy. Slight contusion may result in a traumatic neuritis with paresis and pain which are temporary, lasting but a few weeks or months. Continued stretching of the nerve from incarceration will cause permanent paralysis in its distribution, and rupture will, of course, give immediate and lasting symptoms. Allis records one case of posterior dislocation which was seemingly reduced as far as the position of the head could be determined, but the leg still maintained a slight amount of flexion, and there was numbness on the dorsum of the foot. Months later, in demonstrating hip luxation on the cadaver, he encountered the same objective findings and made an immediate dissection, finding the sciatic nerve wound about the femoral neck.

Reductive attempts by circumduction are the efforts which are likely to pick up the nerve and cause it to slip over the bone. The head seems to enter the acetabulum, but a slight degree of thigh and leg flexion persist, and there is pain when the leg is passively extended. If a looping up of the nerve can be diagnosed, the treatment must consist either in redislocation by manipulation or an open operation for freeing the nerve by sight. The femur is carried into extreme adduction by the bringing of the affected thigh up across the abdomen, the leg flexed on the thigh. Reduction is again attempted, but if the nerve persists in becoming entangled, open operation is the best recourse. Allis has suggested that after redislocation the nerve should be held taut through an incision in the popliteal region and reduction made. The surgeon must recall that the nerve is very large near the hip-joint, measuring an inch and a quarter in width, so that it may easily be mistaken for other structures and can offer resistance to reduction.

Fractures in the hip region are rare complications of luxation. A very few fractures of the head have been reported in connection with dislocation. Fracture of the femoral neck may occur at the time of dislocation, or, as in most instances on record, it has followed attempts at reduction. The prognosis as to life is poor in these cases, because the violence has been extreme. Reduction by direct pressure and manipulation is reported, but under present surgical conditions, an open operation which would fix the head onto the fractured neck after replacement in the acetabulum would be the treatment of choice (see Fractures of the Femoral Neck). Shaft fractures are also uncommon accompanying hip dislocation. Hamilton, in his last edition. collected 4 cases. Allis reports having seen 3 cases. In the la

at the Cook County Hospital we have had 1 case. Treatment is first directed toward reduction of the luxation and subsequent care of the fracture. Bigelow suggested the use of coaptation splints applied firmly around the thigh to hold the fractured bone and manipulation following directed mostly toward flexion. The management of the dislocated head locally, the surgeon grinding it into the hip socket by digital pressure, would complete the efforts at reduction. Failure of manipulation must be followed by immediate open operation. The head could be reduced, and if this were wished, the bone fixed at the fracture site by an internal splint. Two incisions would be needed when the fracture was located at some distance from the joint.

Associated pelvic fractures, especially those in connection with central dislocation of the femur, have been discussed under the heading of Fracture. The prognosis is grave.

Accidents in, and complications after, reduction are now rare. Formerly heavy mechanical traction by the use of pulleys sometimes caused fracture of the femur and increased the opportunity for suppuration about the hip by tearing the soft structures and increasing the hematoma. Suppuration may follow an easy reduction, the source of the infection arising from bacteria in the blood. One must avoid violent rotation and extreme abduction of the femur to guard against these accidents.

Prognosis and After-treatment.—The prognosis of reduced uncomplicated hip luxations is good, but little disability following most cases. In Steinke's recently dislocated 10 cases referred to, the hospital stay averaged from three to forty-seven days. One case ended fatally on the third day, the others with one exception of probable nerve injury, gave excellent results, upon examination from two months to four years after. In the last two years at Cook County Hospital the stay has varied from one day to two months. In usual dislocation it is sufficient to place the patient in a bed and support the leg by sand-bags or a padded Liston splint. In exaggerated positions of the head with extreme laceration of muscles and capsule a Buck's extension with ten or fifteen pounds' weight may be applied for a week or ten days. If there is a tendency to the development of an arthritis, the leg can be placed in a circular body plaster cast and left there two to three weeks. A position of abduction is maintained. The general rule is that the sooner after luxation the reduction occurs, the shorter the convalescence is. In a small proportion of luxations the joint remains tender, and motion is restricted, because of muscle laceration or a secondary arthritis. When reduction is not performed soon after luxation, it becomes more difficult to accomplish, and the limb does not support body weight when it is inverted and adducted, as in posterior luxations. A pseudo-acetabulum develops about the head in its new position, and a compensatory scoliosis of the spine and tilting of the pelvis may permit the foot to rest on the ground and the limb to be used in locomotion. A lift on the sole of the shoe may aid in walking, but these legs tend to become progres-

sively shorter, and really belong to the operative class when irreducibility is first demonstrated. Anterior dislocation rarely gives shortening, and when a new socket forms about the head of the bone, the limb may become serviceable even without a crutch or cane.

Old dislocations of the hip are seldom seen. Boehnke's case of a three-year-old boy was found unreduced after being three months in a cast. It was reduced by open operation. Reduction may be successful through manipulation and traction, but it is a difficult task, and fracture of the femur is a likely complication. Prollet,[1] in a collection of 46 cases, found that in 11 failures of reduction there were 4 deaths and 8 fractures resulting. Dollinger[2] has had a large experience with 22 cases, only 4 of which were successfully reduced by manipulation. Although there are reports of cases reduced by manipulation after months of time, I doubt them very much. Dollinger's longest case out of the socket was nine weeks. If the roentgenogram shows bony proliferation or partial ankylosis, manipulative attempts will surely fail and may lead to grave complications. The age of the patient—children offer a better prognosis—and a tendency to osteoarthritis must be considered. Ankylosis may follow manipulative reduction.

If at the present time the position of the limb is unhappy, functional loss is great, and the roentgenogram shows any bony interference, the choice of treatment is arthrotomy and open reduction. For posterior luxations an incision is made from the posterior inferior iliac spine to the base of the greater trochanter. All connection of the head to the pelvis is cut through after the head is found lying under the gluteus maximus. The thigh is then brought into strong inward rotation and flexion to remove the neck and shaft from the approach to the acetabulum. Over the acetabulum are found stretched the obturator internus, the gemelli, and the pyriformis. These muscles are pulled upward, the acetabulum is cleaned out, and the head is levered in by circumduction. In the anterior luxations, the access to the acetabulum is covered by the trochanter and the muscles mentioned. The muscles are retracted downward, and the acetabulum is cleared. Flexion and rotation inward of the thigh removes the trochanter from its blocking position, and the head is subsequently levered in, first being freed by dissection from surrounding tissue, if it is adherent. It may be necessary in some cases to resect the head, because it has been comminuted, or because of the intense adhesion. In 4 old posterior luxations, Dollinger reduced 3, one of three and a half months' standing. The fourth necessitated resection of the head. In 5 old anterior luxations 2 heads were resected, 2 were reduced and on 1 an osteotomy (subtrochanteric) was performed that a better position of the limb might be obtained. Of the 17 arthrotomies detailed in this report, 12 resulted in reduction, 4 in resection of the head, 1 in osteotomy, and 1 in death. Of the 12

[1] Thèse de Lyon, 1903.
[2] Ergebnisse der Chir., iii.

repositions 5 suppurated, 6 healed per primam. Dollinger prefers the open reposition and considers that children offer the best prognosis.

Cleaning the acetabulum may result in subsequent ankylosis. When this condition is feared by the surgeon, the head should be rounded off and a fat fascial flap interposed, as in arthroplasty. If the head is resected, an ankylosis to the ilium in a position of abduction is preferable to a movable weaker joint.

An old luxated hip-joint which bears weight and permits some motion will often improve in function, and the case must be studied from all sides before the patient is subjected to operation. Infection and ankylosis without suppuration are the foes of operative procedure, but position can be improved, and in skilled hands these dangers are minimized.

CHAPTER XXIV.

FRACTURE AND DISLOCATIONS OF THE PATELLA.

FRACTURES OF THE PATELLA.

In my collection of fractures at the Cook County Hospital, Chicago, fractures of the patella equal 1.67 per cent. of the total number. More than twice as many cases are found in men as in women, most instances occur in the fourth decade of life, and very few are open fractures. Scannell,[1] in a tabulation of all fractures in the Boston City Hospital for forty-two years found the patella broken in 668 cases out of a total of nearly 39,000 fractures, to which he added seven years of further records, bringing the total of patella fractures to 882, of which 871 were closed and 11 were open. This injury is rare before fifteen years of age, as the bone is not fully formed until after puberty, probably not before eighteen years of age.

Causes.—The causes are of two kinds, direct violence, as in a blow or fall on the patella, or indirect violence from an unexpected forcible contraction of the quadriceps femoris muscle or sudden flexing of the leg with this muscle in strong contraction, as in case of a foot caught between immovable objects and a sudden pushing over of the body into a sitting posture while effort is being made to stand erect. Longitudinal cracks or breaks in the bone are undoubtedly caused by direct violence, as a smart tap on the knee with the leg in part flexion, or a similar trauma received by the striking of the knee against a heavy object or sharp edge in walking, the blow being usually received with the leg in partial flexion (Fig. 482). Falls or direct violence also account for the incomplete fractures or the complete type without separation, but the greater percentage of all breaks with the customary transverse line of fracture in the lower portion are due to indirect violence. Definite history at the time of accident is difficult to obtain because of the excitement or the pain, and as most of these injuries immediately result in a fall, the patient naturally ascribes the whole trouble to the fall. Those cases in which the damage is sustained by a person in a squatting position or by known direct violence are about the only ones which give a clear history. Falls on the knee, or both knees, are common, and yet we do not find many resulting in patellar fractures, nor are there many instances of simultaneous fracture of both patellæ, which would be expected if direct violence were the usual cause.

[1] Boston Med. and Surg. Jour., November 15, 1906.

Steinke[1] reported 2 cases of simultaneous fracture of both patellæ and collected and analyzed all the cases in the literature up to that time, 44 in all, of which 28 mentioned the manner of fracture. This was found to be indirect violence in about two-thirds of the cases.

With the leg semiflexed the patella lies at the highest point of the condyles of the femur in a position of weakness and non-support on the intercondyloid fossa, as shown in the figure (Fig. 483). Sudden strain from flexion of the leg or contraction of the quadriceps will thus tend to snap the patella and tear the ligaments.

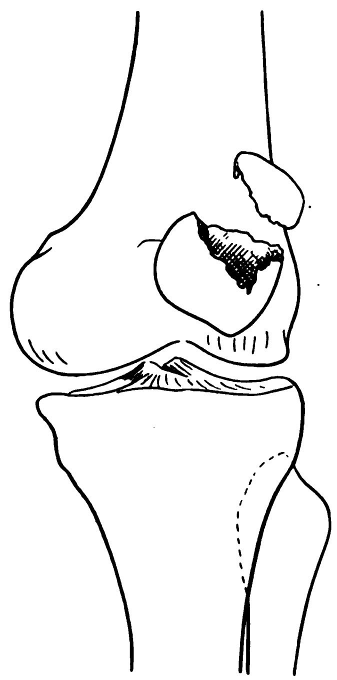


Fig. 482.—Fracture of the patella from direct violence caused by an object striking the bone. The upper outer quadrant is broken off and carried upward and outward by the force and contraction of the vastus muscle.

Blows which cause cracks in the bone or complete subaponeurotic fracture without separation, result in predispositions to subsequent injury of the same character or complete fracture by indirect violence, as in a case reported by me[2] (Fig. 484).

Pathology. — Transverse or oblique fractures are of most frequent occurrence when the cause is indirect violence. Corner[3] gives this finding in 83 per cent. of cases, and Kroner[4] found longitudinal fracture in 3 cases, oblique in 8 cases, transverse in 166, stellate in 6, and comminuted in 22 of those analyzed by him. This form of fracture is for the most part situated in the lower half, as the triangular-shaped patella is the most common, but it may be found at any site in the bone, involving its whole diameter or merely one corner (Fig. 485). The line of fracture may be straight through the substance of the bone, or pass in an oblique direction or be step-like or curved, the line of one surface lying at a different level from that of the other with a sharp right-angled or curved plane of separation. If lateral pressure or force has been combined with the indirect violence freakish lines of displacement result, involving but part of the bone in its anteroposterior plane and yet causing complete separation in the longitudinal axis. In longitudinal fractures, complete separation may not be present; if it is present, one fragment may be dislocated

[1] Ann. of Surg., lviii, 510.
[2] Surg., Gynec. and Obst., May, 1911, p. 469; Wegner, Deutsch. Ztschr. f. Chir., 1900, Bd. lvii, S 157.
[3] Ann. of Surg., lii, 707.
[4] Deutsch. med. Wchnschr., xxxi, 996.

out of its position laterally (Fig. 486). All of those that I have seen involved the outer portion of the bone, and the outer fragment was displaced outward, pulled by the vastus externus insertion. If the fracture line passes through the frontal plane and is complete with anterior and posterior fragments, one of these may be displaced laterally, but the mechanism in these cases is more apt to be a primary dislocation with subsequent splitting of the bone and a return to normal position of one fragment.

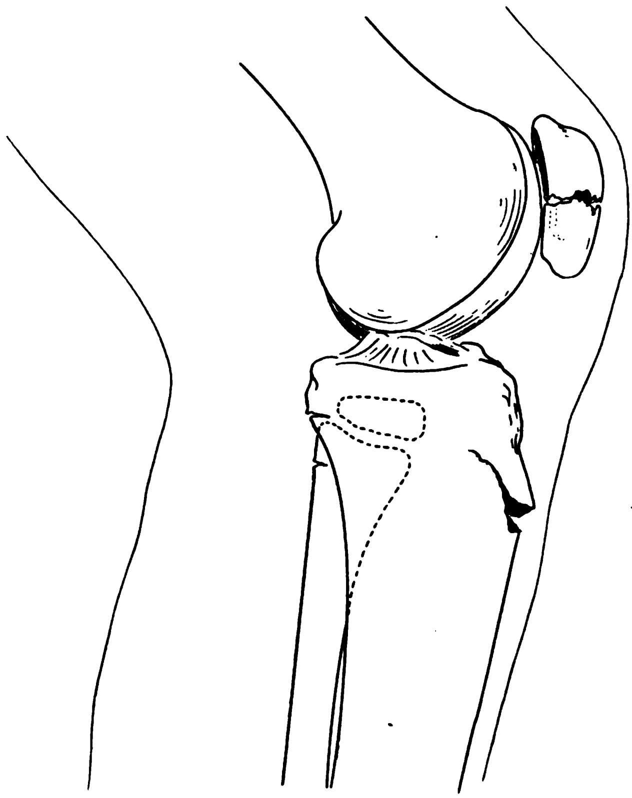


FIG. 483.—Position of non-support of the patella on the intercondyloid notch. Complete transverse fracture of the patella without much displacement. The patellar ligament has torn out the tibial tubercle, instead of being itself ruptured, and there is a coexistant Schlatter's sprain.

Comminuted, stellate, and some oblique fractures are due to direct violence and are of infinite variety (Fig. 487). They may follow simple transverse fracture with a subsequent fall furnishing direct violence to comminute the bone. The right patella is more frequently fractured than the left.

Displacements.—In the complete subaponeurotic type or in instances of a crack without tearing of the periosteal covering, the separation may be practically *nil.* Displacement depends entirely on

comitant rupture of the fibrous aponeurotic investment of the bone and the tearing of the lateral ligaments and synovial membrane of the knee-joint. The bone may suffer a comminuted or stellate fracture, and thus be split up into many fragments which do not separate on account of the intact covering. The degree of displacement in transverse or oblique fractures in which the periosteal covering is torn is further determined by the extent of this tear laterally into the structures of the joint. Immediately after the accident, a transverse fracture will show from one-quarter to one inch separation between

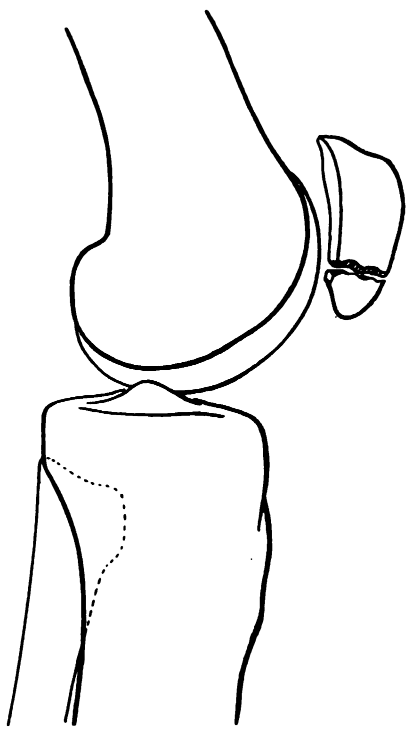


FIG. 484.—Complete subaponeurotic patellar fracture without separation of the fragments or appreciable capsular tear.

the fragments, the sulcus being plainly seen and palpated. Should hemarthrosis with distention occur, this separation becomes greater in a short time. While the lower fragment is held securely by the patellar tendon, the upper fragment tends to retract further through contraction of the quadriceps muscle, which has lost its anchorage to the tibia. The lower fragment is rotated a little so that its broken surface tilts forward, while the upper fragment usually takes the opposite displacement, its broken surface tending to turn toward the joint cavity or be rotated *posterior* (Fig. 488). Any modification of these positions is found, even the reverse of that given, because of

direct violence or the incarceration of the fragments in shreds of periosteum.

Angular displacements laterally with no great separation are due to uneven tearing of the capsule, one side giving way completely, the other holding by enough tissue to pull the fragments into that position. Anterior or posterior angular displacement may come from the same cause, the fibrous layer in the front tearing while the posterior layer and synovial surface remain more or less perfectly intact and hold the posterior margins of the bone closer together.

Fig. 485.—Usual type of patellar fracture, transverse near the lower third. Note the tiltingof the fragments which are drawn by their respective attachments.

Fig. 486.—Longitudinal patellar fracture. Slight outward displacement of the small fragment pulled by the capsule and vastus externus muscle.

It should be remembered that the pressure of bandages or pads can also cause these angular displacements, in which positions the bone may heal. I recall one such case in a workman who had been recently treated by the operation of wiring. The wire had completely encircled the bone, brought the fragments into apposition and resulted in strong union, and yet he could not flex the leg more than 30 degrees. Examination showed firm union, with no trouble in the joint, but beyond 30 degrees a firm opposition to flexion, which was explained when a lateral view by roentgenogram was studied. The

operator had secured contact along the line of fracture, but the apposition was imperfect, inasmuch as the upper fragment was tilted at a slight angle so that its fractured surface pointed somewhat backward and its posterior margin overhung that of the lower fragment. When attempt to flex the leg was made this projecting edge of the upper fragment impinged on the femur and prevented further flexion.

More important than that of the bone is the injury to the capsular structures. By this, as previously mentioned, the amount of displacement of the osseous fragments is governed. It is found in all cases

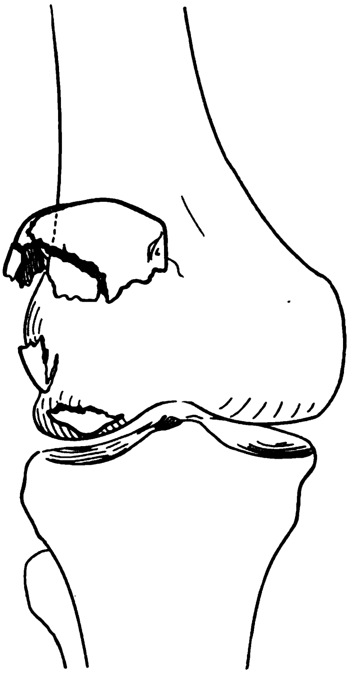


Fig. 487.—Comminuted fracture of the patella. Note the several fragments and the wide separation indicating extensive capsular tear.

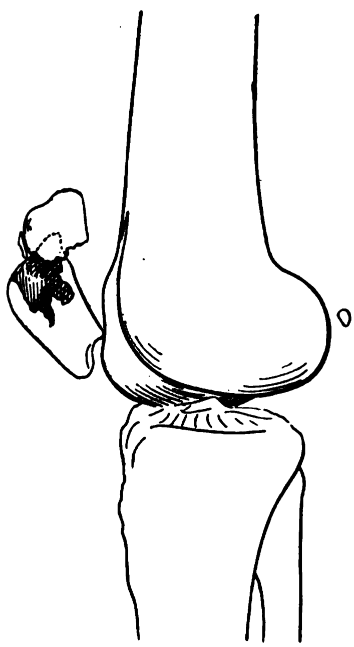


Fig. 488.—Lower fragment of fractured patella rotated to tip forward a little. Upper fragment looks backward toward joint.

of complete fracture and probably also in incomplete fracture, most cases of which are not opened for verification. The tear in the periosteal fibrous covering is generally at a different level from that of the fracture, so that when the fragments separate the edges are covered on at least one side by the fringe of the fibrous tissue which falls between. Macewen[1] first demonstrated this in 1887. It may be very ragged and shredded or have a distinct sharp line of tear, as if it had been cut. Extending laterally in direct continuity are the tears in the lateral ligaments which may reach down toward the back

[1] Ann. of Surg., li, 177.

of the knee-joint. The ligaments can be separated for several inches, the tear involving the less elastic fibrous structures and sparing in part the more elastic synovial membrane. Knowledge of this pathology is essential to proper treatment and prognosis. If the osseous fragments have lying between them a thick fibrous tissue one cannot hope to obtain bony union unless that is removed. If the lateral ligaments and synovial membrane are torn and separated they will tend to remain apart even if the leg is put in complete extension and pressure is made on the fragments of bone to approximate them. They contract and are bulged out by the blood with which the joint is distended. Healing by cicatrix is a long and slow process. When motion is attempted this cicatrix will prevent full freedom; moreover, the fibrous union obtained between the bone fragments may stretch, and there results a knee weakened and unstable, both in its patellar and ligamentous relations. Blood in the joint is almost constant, especially when the capsular structures are torn or direct violence has been sustained. This causes distention, and the clots bulge up between fragments of bone or ligaments. Organization of the clots may lead to a fibrous ankylosis, or, if infected, to pyarthrosis and subsequent stiff joint.

One further point in the pathology which must be clearly understood, refers to the anatomy of the quadriceps extensor insertion and the placement of the sesamoid patella in this tendon. The rudiments of the patella appear about the tenth week of fetal life, and ossification commences from one centre, usually about the third year. This ossification may be tardy in its onsets and the bone may remain small, so that a rudimentary patella results. This is very commonly associated with other congenital defects which involve the quadriceps, dislocation of the hips, or defects in development of fingers and toes.[1] Pearson[2] reported 3 cases of congenital defects of both patellæ which were all related, and other men have recorded instances of congenital absence of this bone.[3] Congenital absence or lack of development is always associated with impaired function, and as a rule the upper end of the tibia and the femoral condyles are well developed, but the tendinous insertion of the quadriceps may be a fault, or the knee may be subluxated, or there may be some other associated congenital deformity. Thorndike[4] collected 50 cases of congenital absence or tardy development; 29 of these were bilateral 21 unilateral (Figs. 489 and 490).

The non-development of the patella is caused most frequently by faulty position, either from congenital luxation or malinsertion of the patellar tendon, which deprives the quadriceps insertion and the bone of a normal amount of stress and functional irritation that are necessary for full development. The sesamoid bone, following the

[1] Bogen, Ztschr. f. Orthop. Chir., 1906. [2] Lancet, 1899, i, 22.
[3] Wuth, Revue d'Orthopedie, 1899, x, 338; Senftner, Arch. Pediat., New York, 1904, xxi, 837; Heine, Berlin klin. Wchnschr., xli, 498.
[4] Tr. Am. Orthop. Assn., Philadelphia, 1898, xi, 337.

rule of all sesamoids, is developed in active tendons which are subject to much pressure and trauma in their action over a joint. The more the bone is exposed to these conditions the larger and more protective it becomes, for it acts as a defense to the articulation, distributing the force of trauma to which the knee is constantly exposed, over a wider area than if it were not present. It also acts as a pulley for the leverage action of the quadriceps, keeping its tendon spread out and giving better surface action for extension power around the condyles.

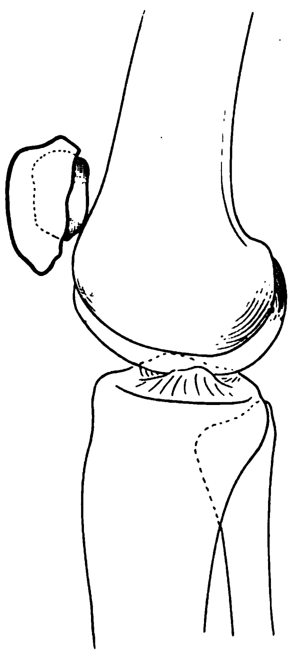


Fig. 489. — Unusual development of the patella. There was no history of trauma and the main portion of the bone retained a normal outline. The secondary mass was distinctly palpable and the discovery of the bipartite character was incidentally made by the roentgenogram. This may be a case of two centres of ossification which have fused.

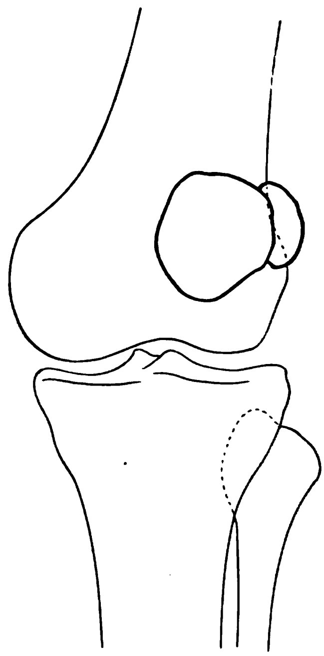


Fig. 490.—Anteroposterior view of Fig. 472. There is no evidence of fracture in the body of the patella. The secondary mass has an outline which resembles the knee-cap.

Eighteen cases of congenital absence of the patella were collected by Little, and Rubin[1] has added 3 more, all occurring in members of the same family.

Some connection between absence or incomplete development of the thumb nails and patellæ seems to exist. Rubin's 3 cases suffered no inconvenience from the lack of patellæ and the only explanation of the condition which could be offered was a common rickety history.

In acquired absence of the patella, following operation for its disease

[1] Jour. Am. Med. Assn., June 19, 1915.

or fracture, this protection is lost, and though it may seem unnecessary for useful function in walking, there is always loss of power after its removal, even if the quadriceps tendon has been carefully closed over the gap by plastic operation. If removed subperiosteally it may regenerate. Grubal[1] reported a case in which the patella was so removed for tuberculosis, and after one year it had reformed, slightly larger than normal, and the patient had a slight limp in walking. Heineck[2] collected 21 cases of removal of the patella, 7 of which were on account of fracture, and concluded that all were followed by functional impairment.

Much of the functional change depends on the condition of the reserve extensor power of the leg, that is, of the expansions of the tendinous bands of the vastus externus and internus that pass to the sides of the patella and are not inserted directly over it. If the patella were carefully lifted out of its bed and these fibers and the lateral bands of the fibrous capsule were not disturbed, one would anticipate little functional loss and a possible regeneration of the bone. This is the pathology of those cases of fracture, often with comminution, where there may be as many as ten fragments with some separation and relatively little loss of function, the patient being able to walk.

In comminuted fracture with laceration and opening of the joint separated bone fragments may drop down into the joint and demand removal.

Resultant deformities after fracture are:

(*a*) Atrophy of the quadriceps from prolonged immobilization, because the condition resulting from the fracture prohibits use of the muscle, or because the patient does not coöperate to obtain flexion and institute active use of the leg.

(*b*) Adherence of the upper fragment to the condyles of the femur. This condition, fortunately not frequent, leads to great loss of function. The lower fragment rarely becomes adherent, but in the healing, ossification may extend down into the patellar ligament and impair the joint function (Fig. 491).

(*c*) Absence of union, either bony or fibrous, between the fragments. The lateral structures unite strongly enough to permit some return of function, but as use progresses and no union exists between the fragments they tend to separate. If a fibrous band unites, together with the lateral support, it may stretch until considerable separation results, but if some of the reserve extensor power of the thigh remains intact, function may be quite satisfactory.

Fibrous Union.—Fibrous union is the rule between the bony fragments in most cases not treated by operation and probably in many operated cases, but in the latter instance this union is more stable and has better backing of the strong lateral ligaments, if approximation is performed with complete understanding of the pathology. Fibrous union is more common after transverse than after oblique fracture.

[1] Bull. de la Soc. Anat. de Paris, 1899, i, 620.
[2] Surg., Gynec. and Obst., ix, 177.

The several factors which inhibit coaptation of the fragments favor fibrous union, namely, contraction of the extensor muscles, tears in the lateral aponeurosis, intra-articular hemorrhage, fibroperiosteal interposition, and tilting of the fragments. Bony union does follow non-operative treatment, as has been shown by the Roentgen rays many times. Morestin[1] showed such a specimen. Others after wiring operations were reported by Jowers[2] and Dreyfus[3] in a dissecting-room subject. Phelps[4] and Chiari, 2 cases, 1 five and 1 seventeen years

FIG. 491.—Widely separated fragments of the patella complicating other fractures, adherent.

after injury.[5] With treatment of today we look for union, often bony, in 9 cases out of 10.

Open fracture is rare, as the statistics show. It is generally due to direct violence at the time of trauma, the skin being burst or cut through and the joint opened. Open fractures frequently occur in instances of refracture, particularly when the incision is made to lie

[1] Bull. de la Soc. Anat. de Paris, 1896, 5 ser., x, 624.
[2] Lancet, 1905, i, 363.
[3] Bull. et Mem. de la Soc. Anat. de Paris, 1904, vi, 48.
[4] New York Med. Jour., lxviii, 871.
[5] Prager, Med. Wchnschr., xxx, 35.

across the body of the patella. Imperfectly healed or young scars, or adherence between the broken bone and the cutaneous tissues and scar cause all to be torn open at once in refracture. More will be said about this in connection with treatment.

Symptoms and Diagnosis.—In frank fractures no difficulty is experienced in finding a displacement. If a fall or direct violence has been the cause, the patient finds that his knee is painful, he cannot use it to walk well, and he may notice the separated pieces of bone (Fig.

Fig. 492. — Comminuted patellar fracture. There was little difficulty in detecting several pieces by palpation. Part of the capsular structures are intact in this case because there is not a wide separation of fragments.

Fig. 493.—A fairly wide separation of fragments. Complete extension of the leg with pressure on the pieces permitted a coaptation and a resulting crepitus. The fragments could also be separately tilted by manipulation.

492). Indirect violence with separation of the bone may be accompanied by an audible snap or a feeling of giving way and sharp pain in the knee. Some ability to walk may persist, especially if the fragments are not widely separated (*i. e.*, if the capsular tear is not great), for the quadratus muscle retains some extensor power by hyperexertion *via* its lateral fibers. In incomplete or non-separated fracture, though the pain may be severe, loss of function is not great, and walking or limping is quite possible.

A patient lying with the leg extended is unable to raise the heel

from the bed. Another sign has recently been emphasized by Dreyer[1] which he considers of importance in determining the type of treatment necessary. A case used for illustration had a separation of 1 cm. between fragments, and the man could not extend the leg. Extension was applied to the *thigh*, following which the patient could lift the leg; but if the extension were removed the disability appeared at once. This test determines in part the laceration of the accessory or even the primary extension apparatus of the leg, and Dreyer believes that if the power to elevate the leg appears after the extension is applied to the thigh, the case should be treated conservatively and not operated upon. His opinion has been confirmed by Haeberlin,[2] who reports a case with bony separation of one and a half fingers' breadth in which the application of the Dreyer test demonstrated ability to extend the leg. Open operation proved that the muscular apparatus was not torn across.

Swelling of the knee, increasing pain and loss of use follow very quickly, as the joint becomes distended with blood and transudate. Palpation of the patella with the leg slightly flexed reveals the loss of continuity in the bone and the sulcus between its fragments in which one can often lay a finger. Sometimes one fragment may be small and widely separated. By hyperextending the leg and pressing the fragments the operator can rub them together and elicit crepitus. This is painful. When the capsular tear has not been complete and the bone is not separated, more difficulty in diagnosis exists. If the fragments are at all mobile, through the holding of one firmly a false point of motion, hinge-like, may be demonstrated (Fig. 493). Swelling of the joint with pain on manipulation of the patella, or a spot of intense tenderness on it leads to a probable diagnosis of incomplete separation of fragments, and recourse to skiagram should be taken. Differentiation lies in hemarthrosis from trauma, in which the patella is found intact but possibly floating on the distended joint and not painful, or from sprain fracture of the ligamentum patellæ. In this condition the ligament is pulled away from the patella generally at the upper margin, the capsular structures may or may not be damaged. The patella may lie at its normal level and show no damage by the Roentgen rays, but examination reveals a sulcus just at its upper border when the quadriceps has ruptured. 255 cases of rupture of the quadriceps tendon were collected by Walker.[3] Of these 140, were below the patella and 115 were above. Hawkes[4] reports a case of this kind in which the tendon and capsule of the joint were both sutured with a happy result. Suckett[5] records a case in a man aged fifty-seven years, who fell while drunk and could not walk or extend the leg. The patella was found on a level one and a half inches higher than its fellow. On flexion it did not move downward. It was freely movable, and its

[1] Zentralbl. f. Chir., Leipzig, xli, No. 22. [2] Ibid., No. 40.
[3] Am. Jour. Med. Sci., 1896, cxxxvii, 638.
[4] Tr. New York Surg. Soc., November 22, 1911.
[5] Ann. of Surg., lvii, 122.

tendon could not be felt at the lower border. Open operation repaired the tear in the patellar tendon and capsule.

Differentiation, in addition to rupture of the ligament, must also be made from recent traumatic bursitis. This can be done if it is borne in mind that in fracture, even if the separation of fragments cannot be demonstrated, the joint becomes distended, the normal hollow depressions about the patella are lost, and the patella floats on the excess of joint fluid; that is, when the joint is compressed laterally the bone when rocked does not impinge on the condyles of the femur beneath. In bursitis the swelling is more circumscribed and superficial, the patella does not float, and the hollows are not entirely obliterated. But one condition may accompany the other.

Course.—The acute swelling of the knee and its soft parts together with the hemarthrosis and distention within the joint follow the fracture very quickly. If the injury is seen early, further enlargement can be prevented by the application of adhesive plaster (after the parts are shaved) so fitted as to avoid wrinkles or overlapping of the skin, which might cause pressure sores or blisters; or by a snug bandage and the use of an ice-bag. If the joint becomes swollen and after twenty-four hours threatens to interfere with circulation in the leg, its contents can be aspirated aseptically if the hemorrhage is still in progress and clots have not formed. After this, it is compressed by bandage. Slight displacement and separation may be overcome by adhesive bands drawing the fragments together, following which union can be obtained, but even in small separations one is never sure to what extent the capsule lies between the fragments nor how great is the capsular damage. Fibrous union is the result in most cases treated thus, as mentioned above, and though after use the fibrous band may stretch so that some extension power in the leg is lost, walking and ordinary use can be almost normal. Getting up from a sitting posture or attempts to raise the leg while lying down a patient finds difficult in these cases, and cannot accomplish these actions until the leg is a little flexed by the hand, to take up the slack in the extensor muscle. Later, this fibrous union may ossify in its whole length, or the ossification process extend into the patellar ligament. The fibrous union may stretch so much that the function of extension is entirely lost and the fragments are widely separated. Following this the quadriceps atrophies from disuse. When the fragments unite by a bony process through any part of their surfaces good function follows, unless one fragment is tilted to obstruct free movement or the capsular structures are weakened. Small exostoses occasionally develop on either surface of the bone. If on the joint side they may interfere with motion in the knee. During the course of healing the bone seems enlarged, possibly because of its increased blood supply or the periosseous infiltration beneath the fibrous covering. After union this swelling in most cases subsides but can persist, and by its presence interfere with the joint mechanically. Other reasons why flexion is limited can be found in the retraction of the capsule or

fascia lata by the scar, or adhesions within the joint. Loss of the power of extension is mainly accounted for by poor union between the fragments or by imperfect continuity, if the fibers of the quadriceps muscle and the lateral tears in the capsule are not repaired. Even with impaired power to extend if flexion is full and satisfactory, the individual learns new tricks in walking and using the leg, and as he trusts it but little his disability is very slight.

Simultaneous fracture of both patellæ while rare is seen. Steinke's article with report of 2 cases[1] cites 44 cases in the literature, the patient's ages varying from fifteen to sixty-five years. 59 per cent. were males, 88.6 per cent. were transverse, 6.8 per cent. comminuted, 2.2 per cent. stellate, and 2.2 per cent. open. One-quarter of these in which treatment was given (68 patellæ) were not operated upon, but all (51 patellæ) that were operated on, even 1 in which the patella was removed, gave good functional results.

Refracture.—The patella is the seat of more refractures than any other bone in the body, 95 per cent. of the refractures occurring through the line of original fracture. According to Corner,[2] after operative treatment 69 per cent. of the refractures occur within the first year, while in non-operative treatment 86 per cent. of the refractures occur after the first year, but the total percentage of refracture, disregarding the time factor, is the same after both open and non-operative treatment. By means of modern operative treatment with little or no splinting following the repair, early passive and active motion of the joint and quick restoration to functional use, refractures happen less often, as the patient does not have to use crutches so long nor is the knee stiff, helpless, and in the way to make him clumsy and expose him to the dangers of falls and trips. If the separation is very little, rest in extended position will generally lead to union, but if perceptible separation and hemarthrosis are present the repair should be done over. I have operated on refracture cases occurring from five weeks to six months after the original fracture and have always been glad I reopened them. One case with kangaroo suture and no cast was refractured by the patient falling off a chair six weeks after operation. His separation was not quite as great as in the first instance, and at the second operation I found a bloody joint and much of the kangaroo tendon unabsorbed but torn loose. The second operation was done with silver wire and a light plaster splint applied to ensure no third occurrence. Final function was highly satisfactory, and the patient said the knee felt better after the second operation than after the first, a fact which I can explain only by the use of the splint after the second operation.

Refracture occurs in those patients in whom limited flexion is caused by malposition of a fragment or by an exostosis. As the patella lies over a functionally active joint, joint motion is usually free up to a certain point, when it stops abruptly. The patient becomes accus-

[1] Loc. cit. [2] Loc. cit.

tomed to this as time passes on, but under extraordinary conditions the leg may be hyperflexed beyond this point, causing refracture. Attempts at passive motion in the joint beyond a point of safety or when pain and contraction of muscles is caused leads to refracture by the attendant, but most instances are due to violence, as in the original break. If the skin is torn open infection with serious consequence often results.

Fracture predisposes to refracture, and yet many reports in the literature show that bony union was obtained primarily and refracture did not occur through the old site. Remy[1] records 2 cases of the same patella fractured twice, but not in the original line; Henry,[2] 1 case eight months after fracture, not in the same site, and Vallas,[3] a case twenty-six years after the primary break. Murray[4] relates an interesting accident six months after fracture of the patella with healing in which neither the bone nor the callus gave way but the ligamentum patellæ was torn loose.

Treatment.—Referring to the pathology of patella fracture one recalls the obstacles to bony union which are known to exist. Treating the fractures from the mechanical side one recognizes that approximation of fragments alone is not all that is needed for union, because this approximation may be faulty and fibrous tissue lying between surfaces may interfere with union. If great separation exists, the problem of drawing the bone together in face of the distended joint and the contraction of the powerful quadriceps muscle becomes very great, and it is not at all surprising that so many different methods (over 90) have been tried and laid aside on account of poor or inefficient results.

Treatment is divided between non-operative and operative care, and the arguments for and against open operation are the same in the case of this bone as in other bones, with the additional understanding that the operation is really an arthrotomy on the largest joint in the body and on a bone with a poor blood supply, a matter discussed at length in the chapter on Operative Treatment. The local conditions as given in the preceding paragraph must be carefully considered, and if the environment is satisfactory and the separation of fragments demand it, open operation is the method of choice.

Non-operative Treatment.—This method covers a large number of maneuvers. Any one which fulfills the following conditions may be tried: The fragments of bone must be put in apposition; this must be maintained until union has been completed; the *continuity of the tear* in the soft parts, capsule, and synovial membrane should be repaired; and the future functional use of the knee must be guarded. To attain these ends the attendant must use such means as the circumstances, including possibly lack of transportation and his non-familiarity with and uncertainty of aseptic technic, permit. Good results follow non-operative treatment where there is not much separation of fragments and where the more important capsular struc-

[1] Revue de Chir., 1906, xxxiv, 639.
[2] Am. Jour. Med. Sci., August, 1899.
[3] Revue de Chir., 1899, xx, 419.
[4] British Med. Jour., 1898, p. 817.

tures have not been widely separated or the reserve extensor apparatus of the leg is unharmed.

Distention of the joint from the hemarthrosis calls for first attention, and routine treatment as follows can be applied: The leg is carefully shaven dry and a well-padded posterior wooden splint is made ready which will extend from hip to heel. On this the leg is placed and by means of inch-wide adhesive straps applied above and below the fragments, each half overlapping the other, some apposition is attempted. This requires about eight strips on either side above and below, and they can be fixed to the wooden splint for firmness, a broader piece being applied directly over the patella area to prevent tipping of the fragments. In addition to holding the fragments steadily in apposition this compression limits further extravasation into the joint and hastens absorption. Unusual distention of the joint may call for aseptic aspiration by means of a needle thrust in laterally at the joint line, but this should be deferred until several days' compression and application of ice-bags have been used. If enormous distention with great separation is present, the case should be put into the operative class at once. Ill-advised or unclean aspiration may lead to pyarthrosis and loss of limb or death. There is *never* an indication for washing out the joint with any solution at the time of aspiration.

A well-applied roller bandage may later take the place of the adhesive dressing, the fragments should be held together by the fingers during its application. Adhesive strips may loosen, or on account of skin sweating, need renewal or complete removal. The mole-skin zinc oxide plaster or the newer and lighter English adhesive plasters are the best. The foot should be elevated slightly, and the patient must be kept in bed at least four weeks, no flexion being permitted in that time. The thigh and leg may be massaged through the dressing but not to the detriment of the position of the fragments. After this period a light posterior plaster splint or a complete cast is applied, and the patient is allowed to get about on crutches for three or four weeks. Then the splint is taken off for an hour or more each day, massage and active and passive movement of the leg are instituted, and after the eight weeks, if union seems satisfactory in the bone, use of the limb may be started.

The greatest care to prevent a fall, overflexions, or traumata against the knee is necessary to avoid refracture. The wearing of the plaster encasement or splint safeguards against this, but at the same time it should be remembered that by prolonging the immobilization the return of function is liable to be hindered. Six months to a year is the time required for return of expected function, which is governed by the different factors mentioned under pathology.

Operative Treatment.—Undoubtedly the first bone to be treated by open operation for closed fracture was the patella. Severino[1] did the first open suture on the patella in 1598; the patient died.

[1] Magruder, Jour. Am. Med. Assn., liv, No. 23, p. 1843.

There are two operative methods, the subcutaneous and the open. The subcutaneous method is now very little used, and only a brief resumé need be given. To avoid infection and dangerous consequences to the largest joint in the body, many methods have been devised to encircle the fragments by wire or other strong suture subcutaneously without entering the joint. Large curved needles which would pass around the fragments have been used to carry this suture, holes have been drilled subcutaneously into the fragments and wire thus introduced to hold them together. Hooks, such as Malgaigne's, have been offered, whose sharp points entered the skin and tissue above and below the fragments and were then brought together by the force of a threaded bar which could be screwed up. The methods most used were Kocher's, Barker's, Butcher's, and Cecis's. The last-named drilled the fragments and inserted his wire in figure-of-eight fashion; the three others passed approximating ligatures of some metal wire around or over all fragments. König and Kocher, the last chief advocates of subcutaneous methods, have now given them up entirely and are enthusiastically using the open method.

The reasons for abandoning this method are:

(1) Asepsis is not assured.

(2) The fracture practically always involves the joint.

(3) Since fragments cannot be accurately approximated, union may be faulty, with tilting and restricted use of joint.

(4) Fractured surfaces cannot be freshened and interlying tissues removed.

(5) Capsular tears cannot be repaired.

(6) Loose fragments of bone cannot be removed from the knee-joint.

Open Operation.—There is no doubt that the open operation is the best treatment when conditions are such that it may be undertaken without risk of sepsis. "Conditions," means all conditions governing the operative treatment of closed fractures from the hospital technic in general to the operator's individual training. Patellar suture by any of the methods in vogue is first of all an open arthrotomy, and the slight resistance of joints to infection, the destruction and rapid spread of suppurative arthritis with its immediate danger to the patient and the remote consequences from stiffened knee and loss of function, must be paramount in consideration. Knowledge of these dangers has long existed in surgery, yet so exigent has the need of suture approximation of this bone been considered that before our present bone aseptic work was developed, this operation was cautiously undertaken by many operators who took special pains to brush up their aseptic technic for the occasion. At this time the operation is done as routine where indicated, and infection is little thought of, so surely has the technic advanced.

To reiterate, open operation permits the correction of the following pathological points:

1. The tears in the capsular ligaments and the quadriceps femoris tendons.

2. The separation of the fragments, removal of interlying prolapsed fibrous tissues, and tilting.

3. Removal of blood and clots from the joint.

4. Removal of loose bone fragments from the joint.

5. Avoidance of malunion, adhesions, cicatricial contractions of capsular structures, and other mechanical interference with the joint action.

Strong indications for operation exist in simultaneous fracture of both patellæ, or fracture in a patella with the opposite knee stiffened. Contra-indications for open operation are also well established and may be briefly summarized as follows:

Fig. 494.—Complete transverse fracture with slight separation of fragments. Operation in this type of case is debatable and depends on the accompanying injury of the capsular structures or contra-indications mentioned.

1. In diabetics on account of possible interference with wound repair, gangrene, low resistance to infection, and anesthetic danger.

2. In any advanced chronic diseases, as tuberculosis, cardiac and renal troubles, or old age.

3. Subaponeurotic fracture, whether transverse or longitudinal, without separation.

4. Very slight separation of fragments (Fig. 494).

Many collections of a series of operated cases are to be found in the literature. Heineck[1] collected over 1100 cases, Powers, 711 cases,[2] with 3 deaths due to sepsis; Phelps,[3] 420 cases, with 3 deaths due to sepsis, 1 due to carbolic acid poisoning and 2 to delirium tremens. Stimson mentions having done over 250 operations with one slight superficial infection. Delatour[4] reports 101 fractures with 96 operations and no deaths.

Sandrock, from Trendelenburg's clinic,[5] reviewing the cases treated there (Leipzig) from 1895 to 1911, found that there were 116 in all, 84 of which were operated, the youngest case being sixteen years old and the oldest seventy-eight. In this series to obtain relief from a large hematoma, the joint was punctured but once, and the convalescence of all cases averaged 41.6 days. Of the 84 operated cases 49 came back for examination, and it was found that of these 47 had

[1] Loc. cit. [2] Ann. of Surg., xxviii, 67. [3] Loc. cit.
[4] Tr. Am. Surg. Assn., New York, 1914. [5] Deutsch. Ztschr. f. Chir., Bd. cxxix.

bony union and 2 had fibrous union with a separation of only ½ cm. During the seven-year period which covers the collection of fracture cases made by me at the Cook County Hospital I find that there were 185 cases, of which 116 were operated. In the year 1907, 11 cases operated on were all wired, with one infection; the next year 7 were wired and 5 sutured with absorbable material, 1 under each method becoming infected, and so on until at the present time but a small percentage are wired, kangaroo tendon or absorbable catgut being the suture of choice. Out of 116 cases, 7 were infected; 1 reoperated case had been done outside the County Hospital, and was infected on admission. None of these cases suffered death nor badly stiffened knees nor prolonged treatment for infection, so that operative treatment can speak for itself. Alexander,[1] in a series of 56 cases had 2 deaths, 1 in a woman who had a septic abortion ten days after the accident and whose leg was amputated three and a half months later, death following in two weeks, and the other a man, who died of sepsis two months after the patella operation.

Technic.—Preparation of patient and time of operation. Observance of the rules for intact skin and absence of shock, and recognition of the contra-indications are prerequisite. There is divided opinion among the best of operators as to the time after accident that operation should be undertaken. All agree on these points: that shock, if present, should have passed, time should be taken to transport the patient to the best operative environment possible, and active hemorrhage into the joint should have ceased. Most believe that a period of five to ten days should elapse before arthrotomy is done, hemorrhage and joint distention should have ceased, absorption be in progress, and aseptic inflammatory and protective reaction have been instigated in the joint tissues.

Murphy[2] prepares his cases as soon as they are received by injecting into the knee-joint 15 to 20 c.c. of 2 per cent. formalin-glycerin solution of at least twenty-four hours' mixture. This causes an infiltration of the synovial membrane and a production of polymorphonuclear leukocytes, which cofferdam the lymph spaces to prepare for resistance to infection, hastening and aiding the natural process. After seven to ten days, Buck's extension being maintained meanwhile, the fracture is repaired. Those who operate on these fractures at once feel that nothing is to be gained by delay, that their asepsis is efficient, and that the convalescence is shortened by early care. Personally I prefer to wait. No comparative statistics are to be had, as the difference in operators would have to be weighed along with the methods.

The Incision.—Many incisions for approaching the knee-joint are used: one straight, longitudinal or transverse; semilunar concave downward; semilunar convexity downward (Trendelenburg or Hahns); convexity inward; convexity outward; angular incision or H-shaped

[1] Ann. of Surg., liii, 508. [2] Clinics. i, 55.

(see Fig. 495). Any opening of the skin incurs a possibility of infection from the bacteria present in its deeper layers, and most operators, weighing this fact, as well as the closure of the wound immediately over the deeper repair, prefer the semilunar incision with convexity downward from the condyles of the femur nearly to the tibial tubercle. This flap is dissected back until the tear in the capsular ligaments and the separated fragments are in the field. The longitudinal incision fails to expose the field freely, so that repair of the lateral tears is difficult, and the scar also is tender to pressure and kneeling. Ross, discussing Alexander's paper,[1] said that he had seen one case of gangrenous infection in this large incision followed by death. For that reason he favored the transverse incision. With this the usual operative technic is employed. Sufficient exposure by the incision must be given to allow the extreme ends of the capsular tears to be inspected and sutured. The fragments are carefully raised and the interlying fibrous tissue lifted out from between and cut off, or used for imbricated suture, as suggested by Andrews. With the leg extended after the opening of the joint the fragments in fresh fracture are rarely more than three-quarters to an inch apart, and the retraction of the quadriceps seldom interferes with their easy apposition. The tear-

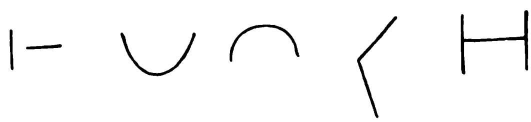


Fig. 495.—Types of incision for opening the knee-joint in repairing fractures.

ing of the capsule or the distention of the joint by blood causes separation. Some operators believe that the joint should be wiped out or irrigated to remove these clots. Various solutions have been used, plain water, carbolic acid of varying strengths up to 5 per cent., bichloride of mercury solution as strong as 1 to 1500, and normal salt solution. Lucas-Championnière ignores asepsis as we believe in it and trusts entirely to washing out the joint with carbolic acid solution. It appears to be an unnecessary danger to the delicate synovial surface with its poor resistance to wash it out with any solution, no matter how sure one is of its sterility. Neither is it needful to soak up the whole field and wash into the joint juices and bacteria from the cut skin surface, nor should the joint surface be abraded by wiping with gauze sponges. The operator's simplest procedure consists in his picking out with forceps such large clots as present themselves in the gaping capsular wound without touching the synovial surface, not bothering to attempt to clean out the whole joint.

Suture Methods and Material.—The different methods practised are: (1) Looping the patella (cerclage) with kangaroo-tendon sutures (or wire), silver or phosphor bronze, the wire passing through the quad-

[1] Loc. cit.

riceps tendon above and below the bone, making circular compression to bring the fragments in apposition, after which the wire is cut off and pounded lightly into the periosteum.

(2) Transverse or longitudinal osseous suture by the drilling of holes through each fragment and the use of wire, silk or kangaroo tendon. These holes should not penetrate into the joint. If longitudinal osseus suture is employed, the drill holes should come out

FIG. 496.—A fracture of the patella sutured with wire which passed around the bone in the longitudinal axis and evidently over the joint surface, a very unsurgical method. The wire has broken since operation performed twelve years before the picture was taken, and a piece has wandered to the posterior part of the knee-joint. The shadow near this wire is the sesamoid in the biceps tendon. Firm union in the patella. The patient's opposite knee is a Charcot joint.

on the fractured surface external to the joint surface. In practice it is sometimes difficult to do this and avoid splitting the fragments (Fig. 496).

(3) Simple suture with catgut or kangaroo tendon of the para- and peripatellar fibrous tissues (capsular). This method is credited to Mickulicz.

(4) Andrews's method of imbrication closure with kangaroo and catgut.

(5) Complete removal of the patella and the turning down of a flap of the quadriceps tendon to fill the defect for attachment into the patellar tendon.

In the 1100 cases collected by Heineck the longitudinal osseous suture was employed in 809 instances and the Mickulicz suture in 240 cases.

Regardless of the method or material of suture used in the first two methods, operators who employ the osseous or encircling suture now also use additional absorbable sutures in the tears in the lateral ligaments. The wire sutures are falling somewhat into disuse except in cases of bad comminution when the encircling method with the various wires or kangaroo tendon is an advantage, or in cases of refracture opened for a second time where the possibility of a subsequent fracture is to be avoided. An encircling wire suture which does not enter the joint seldom gives trouble. Occasionally one leads to irritation if the twisted ends are not buried, or one may break and have to be removed.

Murphy uses a twelve-strand, phosphor bronze wire,[1] and sometimes uses two, one a little above the other to avoid the tilting of fragments. These are knotted and supplemented by catgut in the capsular structures. In closing the capsular structures it is advisable to turn the flaps up so that the inner surfaces face each other like the ectropion of the peritoneum in abdominal closure in order to avoid intra-articular adhesions (Fig. 497).

After-treatment consists of a padded longitudinal splint until the patient is out of the anesthetic, when it is removed, or Buck's extension with a twenty pound weight, or a permanent plaster or wire splint for four weeks, all these to be followed by daily removal and massage with passive motion for two weeks and then crutches, massage, and active use until function is restored. Dreyer[2] advocates the use of an extension bandage on the thigh even when operation is performed, declaring that this protects against the pulling out of the sutures better than casts or splints. Bony union is generally complete in six weeks; little active use is to be permitted until the tenth week. If circular plaster casts are applied, or the limb is immobilized for a long time in the extended position, there is great difficulty in obtaining flexion of the knee. Most cases ultimately (six months or more) regain almost complete use. Murphy believes that the Buck's extension is better than a cast or splint, because it keeps the tibia and femur separated and the capsular ligaments elongated and thus gives less trouble later in obtaining movement and flexion.

The Andrews imbrication method offers the following advantages: Absorbable material, kangaroo tendon or catgut, is used. The fibrous fringe lying between the fragments is used to fold over the opposite fragments and is held by two or three mattress stitches which bring the bone in firm apposition. They pass up beneath this fringe and come out through the periosteal covering of the fragment. An

[1] Clinics, i, 843. [2] Loc. cit.

additional three or four interrupted sutures hold the fringe down to the opposite fragment. The capsular structures are then closed from one extreme of their tear to the other by a continuous suture of catgut. Then the subcutaneous tissues (he uses the transverse incision directly over the fracture) are closed by a buried suture of catgut and the skin closed by clips. This method gives a layer closure much like

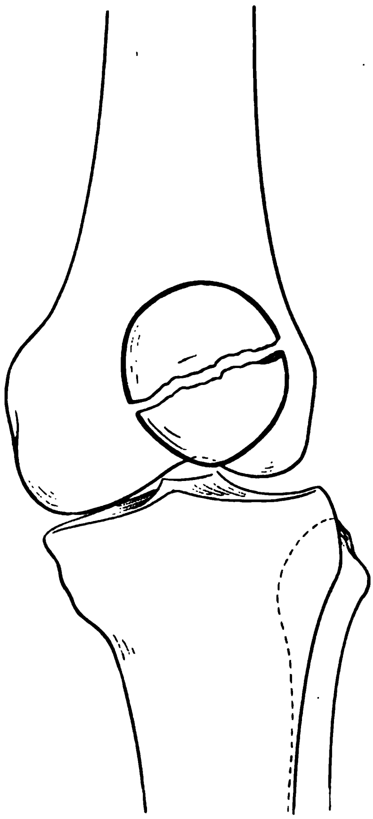


Fig. 497. — Postoperative anteroposterior view of a fractured patella repaired by an encircling silk ligature and catgut repair of the ligaments. Apposition does not seem to be complete in the roentgenogram. Clinically it is complete and sufficient to ensure strong union.

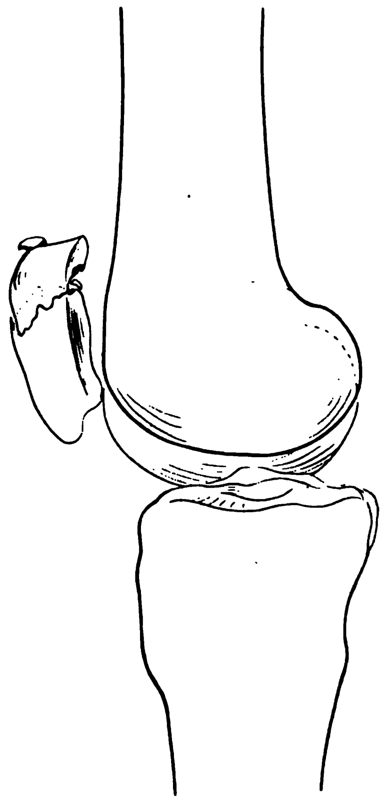


Fig. 498.—Lateral postoperative view of fracture of the patella repaired by the Andrews's suture method with kangaroo tendon. No cast.

the method of closing the abdomen, uses no wire to cause trouble, and if infection occurs in the skin edges, gives it less chance of burrowing down into the joint through the overlapping folds beneath. The after-treatment is as follows: No splint is used. The patient is put to bed. The day after operation passive motion of 20 to 30 degrees is done. In a week nearly 90 degrees of passive motion and much

active motion are possible, so that in three or four weeks the injured knee has practically a normal range of motion, convalescence is hastened, there is no atrophy of the quadriceps, and no delay for the regaining of joint motion (Fig. 498).

Wyeth[1] has suggested a suture of the torn ligaments after washing out the joint through a short transverse incision and the use of heavy linen subcutaneous sutures one above and one below the patella tied outside over a gauze pad. He uses a plaster cast for six weeks, and I see no need for the subcutaneous stitches which favor infection and the cast which favors joint stiffness.

In badly comminuted fractures Murphy removes the whole patella and uses a flap three-fourths by four and a half inches from the central

FIG. 499.—Amount of active flexion secured in the third week in a case of patellar fracture treated by suture with kangaroo tendon and without the application of a post-operative splint.

part of the quadriceps tendon, which is swung down and sutured to the ligamentum patellæ. This does away with trauma to the joint and the burial of any foreign material. His stand in this matter he sustained by exhibition of a case[2] of patellar fracture which happened in the Civil War (Figs. 499 and 500). Although there was five inches' separation between the fragments, the man had a perfect functional use of the limb, a fact showing that man can get along without the patella. He advises users of this flap method to strengthen patellar repair by wiring when operating on fat persons.

Bone transplantation has also been used in fresh fracture. Vulpius[3]

[1] Jour. Am. Med. Assn., 1915, lxiv, No. 21, p. 1752. [2] Clinics, i, 326.
[3] Ztschr. f. Orthop. Chir., 1914, Bd. xxxiv, S. 545.

reports a case of fresh fracture of the lower third of the patella, the lower fragment being badly comminuted. He fashioned a tongue-shaped piece from the superior surface of the upper fragment, swung it down to cover the deficiency in the lower fragment, and obtained prompt healing and good use. Rogers[1] records an instance of re-fracture three months after the original fracture, in which, in addition to the usual suture, he took a graft from the tibia, inserted it beneath the periosteum of the patella, and sutured it there. The result was excellent, and a roentgenogram nine months afterward showed the graft in place, unabsorbed, its under surface blended with the anterior surface of the patella and the line of fracture also bony.

Old fractures, with impaired function, ununited or with attenuated fibrous union, require open operation. If the condition is of long standing, the difficulties in the way of approximating the fragments

Fig. 500.—Side view of Fig. 499, showing amount of early active flexion.

are great. Modern early operative treatment has cut down the number of these old cases, which are really confined to those who are out of reach of surgical care or who furnish some contra-indication for operation at the time of injury. The upper fragment is retracted into the subcrural region and often becomes adherent there; the lower fragment is pulled down toward the tibia and is encapsulated in a fibrous mass. The capsular structures are retracted and fibrous and there is atrophy of disuse in the quadriceps muscle. Walking is very difficult, the patient may be able to shuffle along on a level surface but cannot mount stairs or an acclivity. He is in danger of falls with injury to this knee-joint or fracture of the opposite patella. Full exposure is indicated, the bone fragments are dissected apart, and the

[1] Ann. of Surg., lix, 765.

fibrous union completely removed, the bone surfaces being freshened by a cutting forceps or saw. If there are cicatricial contractions in the capsular structures, these are also excised and repair done as in fresh fracture.

Quenu and Gatellier[1] have reviewed these different methods of treatment and mention Chaput's subperiosteal resection of the upper fragment and Lucas-Championnière's hinge-like reinforcement of the fibrous band with metal wires. They report that results since 1893 have been excellent in 80 per cent. of all cases, good in 17 per cent. and that deaths or failure followed in 3 per cent. The simplest procedure should first be attempted—traction on the patella and quadriceps tendon aided by V-shaped incision along the edge. The tubercle of the tibia may be mobilized completely to secure approximation and be reattached. If it is not possible to approximate the fragments, excision of the bone can be performed and the flap of quadriceps tendon swung down to fill in the gap by attachment to the patellar tendon.

DISLOCATIONS OF THE PATELLA.

Dislocations of the patella are rare and interesting. Lately they are being treated on a common-sense pathological basis. In the records of dislocation studied at the Cook County Hospital for seven years this sesamoid bone was found dislocated five times.

To make clear the subject of patellar dislocations it is necessary to review briefly the anatomy of the bone and its attachments. As stated previously, the bone acts as a protection to the front of the knee-joint and in a position of leg extension lies much higher on the femoral condyles than is commonly appreciated, articulating with the patellar surface of the femur only. This surface consists of a median groove or trochlea, which extends in a downward and backward direction to the intercondyloid fossa of the knee-joint. On the side are the convexities of the condyles of the femur which guard this groove, the medial convexity being broader and more prominent and extending farther up than the lateral. In this groove runs the tendon of the quadriceps femoris muscle, and in this tendon the bone is developed. The anterior or subcutaneous surface of the patella is flat and is covered by a bursa; the quadriceps tendon being firmly attached all about its edge except at the lower front, where the patellar ligament is fastened. On the posterior surface which lies in contact with the femur, are two smooth oval areas which are the articulating surfaces, divided by a vertical ridge into two facets, the outer of which is the larger. Below these two facets the bone comes to a sharp point, which is rough and does not articulate with the femur behind but gives insertion for the ligamentum patellæ. On the inner side of the knee-joint, aiding the capsular ligament in maintaining the patella in position, is the so-called median patella ligament (aileron de la

[1] Revue de Chir., 1913, xlix, 173.

rotule) a firm, narrow band passing transversely backward on the *inner* side of the joint to the iliotibial fascia.

Classification.—*Acute and Chronic or Recurrent Dislocations.*—(1) The *acute dislocations* are divided with reference to the position of rest assumed by the patella and are (*a*) external, the commonest variety, which may be complete, incomplete, rotated on edge, or reversed; and (*b*) internal, which are very rare; (*c*) upward or downward, which are really due to laceration of the quadriceps insertion on the patellar ligament and are not dislocations in the truest sense (see Fracture of Patella); (*d*) backward into the joint between the femur and tibia locking the knee.

(2) *Chronic or recurrent dislocations* can be divided on a pathological basis into (*a*) those following repeated acute dislocations from trauma with a minimum of the bone change in the condyles and joint changes; (*b*) those which are congenital and usually bilateral dislocations; and (*c*) those which are recurrent, determined largely by structural variations of the knee and relaxed ligaments or by paralytic changes.

Causes.—The cause of acute dislocations of the patella may be external trauma received directly on the bone, forcing it out of its place either toward the outer or inner side. Conditions which result in this accident may be found by one riding horseback and striking the knee against an object in passing, or by one falling on the knee with the thigh abducted and violence received on the patella. Muscular action also may be a cause, from sudden forcible contractions of the quadriceps extensor muscle aided by certain predisposing factors. Imperfect action of the muscles produced by cerebral or spinal affections or following acute infectious diseases and toxemias, as diphtheria, may be primary or contributing causes.

Congenital and recurrent dislocations are so intermingled with the pathology of the joint structures that the two must be considered together. In the normal leg the weight-bearing line passes from the anterosuperior iliac spine through the patella along the tibial crest. In knock-knee this line does not pass directly through the structures mentioned, and a weight let fall from the anterosuperior iliac spine to the ground or a line through this spine and the middle of the ankle mortise will fall without the patella and lateral to the knee. Consideration of this line is an important point in the pathology, for, if the ridge of the external condyle is low and guards poorly the groove in which the patella lies, it is not difficult for a sudden contraction of the quadriceps tendon to pull the patella out and over this edge when the foot and leg are everted. The point of insertion of the patellar ligament into the tibia probably plays some part, when this is lateral to the middle line and assists in the deviation of the weight-bearing line from the centre of the intercondyloid fossa. The extended position of the leg with eversion rolls this point of insertion farther out, so that, in contraction of the quadriceps and a shortening of the muscle from the origin to the tibial tubercle, much force is expended, which (aided by the weak resistance of the capsule and median patellar

ligament) influences the lateral displacement of the patella. The condition is further favored by a laxness and superfluity of the tissues of the internal lateral ligament and the joint capsule. The *position of genu valgum of several years' duration* has caused an increase in the size of the internal condyle and a stretching, with resulting laxness, of the capsular structures on the inner side of the joint, involving practically the median patellar ligament. Traction of the quadriceps muscle, besides causing extension of the leg, is partly resolved into another force, which pulls laterally on the patella, causing a constant stretching and weakening of the structures on the inner aspect of the joint. A sudden severe contraction of this powerful muscle, when the foot and leg are everted and the patella rests high up on the femur, easily lifts the patella over onto the ridge of the external condyle, and as this causes sudden pain the leg is contracted, and the patella, dragged down by the patellar ligament, comes to lie outside of the ridge of the condyle. If it is pulled clear down and retains its normal position without rotating, there is a complete outward dislocation; if it rides on the edge of the condylar ridge and does not slip clear over laterally, there is an incomplete dislocation. In sliding over into a position of complete dislocation the patella may be restrained by some intact or shorter fibers of its attachment and be tipped over on edge at any angle. Furthermore, in reaching its resting position laterally it may be completely rotated on its axis until the posterior or joint surface comes to lie anteriorly beneath the skin, so that there is a dislocation with complete rotation.

Pathology.—*Damage to the Capsular and Ligamentous Structures.*—A displacement of such magnitude cannot be accomplished without damage to the soft structures which hold the bone, and in acute complete dislocations, if they are seen before swelling has ensued, the tear in the capsular structures can be palpated through the skin. In fact capsular tear is in direct ratio to the completeness of the luxation, and when the patella is completely rotated there must be capsular tear on both sides of the bone. A case is reported by Tenney[1] of a young man aged twenty-one years, who was wrestling. He felt his knee give out suddenly and noticed the patella standing on edge at the outer side of the joint. He pushed the bone into place while his friends pulled on the leg. Little reaction followed, but the depression became apparent at the inner side of the patella, and an opening in the deeper structures about the joint could be plainly felt through the skin. Open operation was performed, and a tear five inches long opening into the joint cavity was found. It was sutured.

The tears in acute dislocation cause hemorrhage followed by hemarthrosis, ecchymoses about the joint, and in some instances great distention. This swelling may disguise the physical findings. If the patella is completely rotated so that its posterior aspect comes to lie under the skin, the ridge between the facets may be palpated, and

[1] Ann. of Surg., xlviii, 723.

there is practically always a dimpling of the skin over the patella, as it is attached by fibrous bands to the anterior surface and these are dragged up when the bone is turned about.

Recurrent dislocations of the patella following acute trauma can be explained on the basis of insufficient repair of this capsular tear, or a stretching of the cicatricial tissue which fills in the gap after repeated injuries to and distention of the joint. It may happen that a dislocated patella, unreduced, becomes permanently fixed in its new position and function is quite satisfactory. Davis saw such a case,[1] in which operation was refused on account of the good function. If the dislocation has occurred in early childhood and been unreduced, or has followed spinal paralysis or diphtheria, the loss of power in the extensor muscles favors a continuance of the luxation, and the unopposed flexors gradually draw the legs into position of extreme flexion. An instance of bilateral dislocation of this character is recorded by Murphy.[2] The patient, a man, went around in a squatting position, and the condition had endured so long that the hamstrings were greatly shortened, and it was feared that the sudden full extension might rupture or stretch the external popliteal nerve and cause foot-drop.

Dislocations toward the median line are rare, as stated, and as can be understood from the anatomy of the parts. They are due to direct violence received *via* the outer edge of the bone driving it inward and rupturing the capsule and extensor muscle longitudinally. On account of the height of the internal condyle these dislocations tend to reduce themselves when the knee is extended.

Backward luxations, with wedging of the patella between the tibia and femur, are due to rotation of the patella on its transverse axis, the joint surface being usually turned upward. The joint cannot be extended passively. These are always accompanied by great capsular and muscular tearing. Miller[3] says there are but four on record. In Szuman's case the external lateral and crucial ligaments were ruptured.

Symptoms and Signs.—Acute luxation of the patella causes immediate loss of function with pain in the knee and generally swelling. As described in the pathology, the pain of the dislocation often causes the leg to flex suddenly, and what may have been but a partial dislocation is by that action made complete. Hemorrhage from the torn capsule fills the joint unless there is great pressure by the soft parts. Inspection reveals the patella out of its normal bed lying external to the ridge of the external condyle in any of the positions from incomplete to complete dislocation with rotation. The intercondyloid fossa can be palpated empty and the smooth edges of the condyles plainly felt, as can also the patella be palpated in its new position. If the dislocation be seen early, before joint effusion, the tear in the capsule or the ridge on the posterior surface of the patella can be felt in cases

[1] Ann. of Surg., lvii, 74.
[2] Clinics, iii.
[3] Ann. of Surg., lvii, 737.

of complete revolution, and the diagnosis is aided by the smoothness of the joint surface of the femur and the dimpling of the skin where

FIG. 501.—Recurrent outward dislocation of the left patella which is seen lying outside the external femoral condyle, the oblique line of the patellar ligament being discernible beneath the skin.

FIG. 502.—Lateral view of Fig. 501. Notice the lateral position of the patella and the flattened contour of the knee-joint over the condyles compared to the other knee.

dragged upon by bands running to the patellar surface (Figs. 501 and 502).

Diagnosis.—Backward dislocation may be confused with fracture of the patella or other injuries to the knee-joint. The secure locking, the absence of the patella from its customary position, and the lack of patellar fragments are diagnostic and are controlled by roentgenogram.

Recurrent cases of outward dislocation are most frequent in children and occur while they are running with attempts to dodge or stop. Falls may follow and complicate the injury, or, on the other hand, the joint may cease functioning for but a short time because, after many recurrences, the individual knows the condition and replaces the bone by manipulation. If a child has a knee in which complete luxation of the patella frequently happens in running, he finds that he cannot stop suddenly, for the patella will be dislocated outward completely. The quadriceps extensor contraction acts partly as a flexor instead of an extensor, because its force is exerted in a line beyond the condyles; hence under these conditions the patient falls frequently and yet he has no paralysis, nor is he clumsy in other movements.

Differentiation must also be made between chronic dislocation of the patella and fracture or loosening of the semilunar cartilages. This can be made through failure to find tenderness over the sites of the cartilage on the joint surface, through the noting of the free movements of the patella laterally, and through the easy reproduction of the dislocation of the patella by manipulation. This last the operator brings about by having the patient lie on a table, and, slightly hyperextending the leg, bringing the leg and knee near the edge of the table without attracting the patient's attention to the maneuver. Then the leg is suddenly flexed by being dropped over the table edge, the patella at the same time being pushed outward. This causes an acute dislocation with the patella outside of the condyle (Figs. 503, 504, and 505).

Treatment.—Acute traumatic dislocations can in most cases be reduced easily at the time of their occurrence. Any movement in extension with lateral pressure on the bone toward its normal resting place may be sufficient.[1] The usual instructions for reduction are: flex the thigh on the body to relax the quadriceps; fully extend the knee to relax the patellar tendon and to allow the patella to take its position as high up on the condyles as possible; manipulate the patella by pushing it inward to make it ride over the ridge of the condyle; grasping the front of the thigh firmly in the hand to aid the relaxation, push down the quadriceps. The leg is then flexed and the patella assumes a normal position; on account of the capsular tears, the hemarthrosis and synovitis, protection from motion of the joint is needed, and a posterior splint for a couple of weeks is advisable. Buck's extension is also used to keep the synovial surfaces apart, particularly in those joints which have an intense reaction.

[1] Whitelock, British Jour. Surg., ii, No. 5, p. 6.

If there is any tendency to recurrence, a close-fitting bandage should be worn over the knee or a brace applied on the inner aspect of the leg and thigh to prevent inversion of the knee and eversion of the foot, which would favor a renewal. Various pads and knee-braces have also been suggested to hold the bone in its proper position.

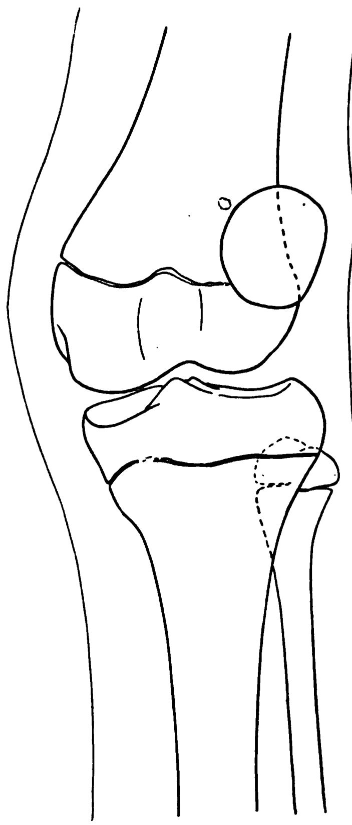


Fig. 503. — Recurrent outward dislocation of the patella. There was some knock-knee present and the patella is found riding over the external condyle. The patient was nineteen years old, the epiphyses in the long bones being still unclosed.

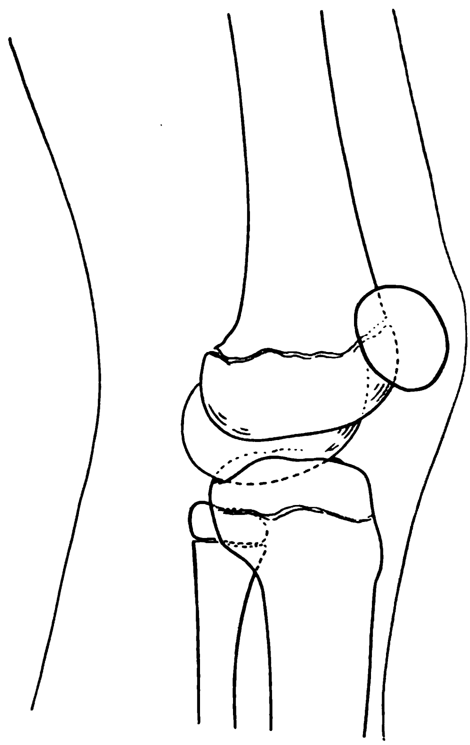


Fig. 504.—Lateral roentgenogram of recurring outward dislocation of the patella, the shadow of which is heavily lined to show its turned position lying on the outer side of the external condyle. Case treated by osteotomy of the femur and subsequent reduction of the patella with capsulorrhaphy.

Old cases, congenital and bilateral, or with a history of many recurrences, can also be treated by braces or pads and maintain some function unless contraction of the leg in flexion has occurred and an upright position lost. These cases are, however, best treated by radical operation. The same may be said of recurrent cases in youths with lax knee-joints and marked knock-knee. Firm braces may give these patients freedom from recurrence, but the shortest and surest treatment is by open operation.

Operative treatment consists in several methods. If the knock-knee is prominent and the dislocated patella can be easily reduced, an osteotomy to straighten the femur just above the joint may cause complete cure if firm splinting is applied until the bone has healed, and a brace or cap is worn afterward for some time. This is a subcutaneous transverse osteotomy done by a saw, or, through a small lateral incision with retraction of the important structures, a large chisel can be used in children.

Acute cases do better and are less apt to recur with an open operation (arthrotomy) of the knee. If they are of distinctly traumatic origin we know that the capsule and probably the quadriceps muscle are torn longitudinally for a varying distance. Open operation with

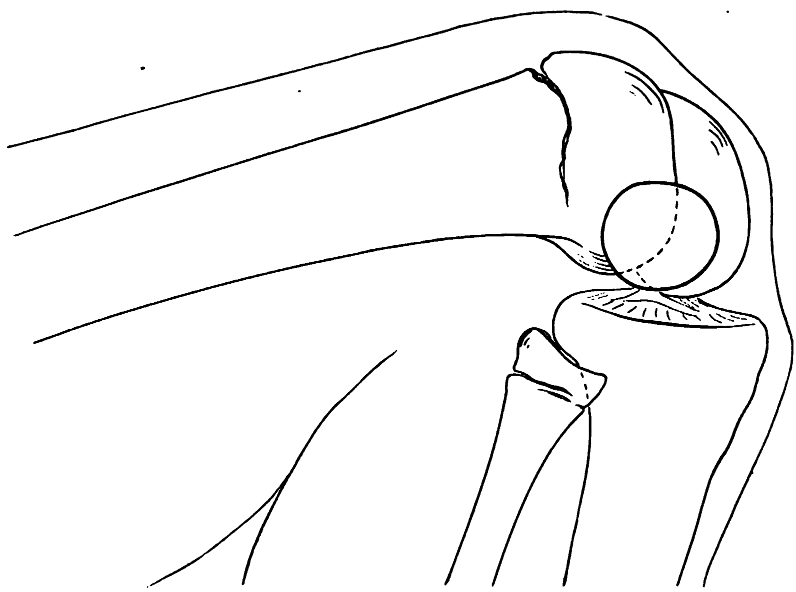


FIG. 505.—Position of the patella lying on the outer side of the external condyle when the leg is flexed.

suture of these important structures looks toward a control of the bleeding, a firm ligamentous union and a shorter convalescence. Whitelock[1] describes 3 cases. In the first one the capsule was torn from the edge of the patella for a distance of four inches. The skin and superficial fascia alone protected the joint, as the medial lateral ligament of the patella and the vastus internus had been torn asunder. Such an operation leaves less scar and does not favor a weak joint from relaxed ligaments after the effusion has subsided.

Acute cases which cannot be reduced by manipulation or which show marked capsular tear should be treated by open operation as

[1] Loc. cit.

soon as possible. The incision is longitudinal, about four inches in length along the inner aspect of the front of the knee-joint. This usually exposes the tear in the capsule as soon as the superficial structures are opened. The patella if unreduced is lifted over the ridge of the external condyle by external manipulation, and the capsular ligament is firmly closed throughout its tear by catgut sutures with the usual aseptic technic. An additional continuous subcutaneous stitch is added above this and the skin is closed with clips or horse hair; no drainage is used. A splint with the leg in extension is worn at least two weeks, then passive motion in the direction of flexion is begun. Weight should not be borne on the leg nor active use made of it until all swelling in the joint has subsided, with a minimum of four or five weeks from time of operation.

The operative treatment of congenital, bilateral, or complete recurrent luxation has been slowly improved since Kocher's operation described in 1907.[1] This operation consisted in carrying the lax part of the internal capsule over the patella and suturing it to the outer side of the bone. These two ends can be attained with or without opening the joint, depending partly on the duration of the condition and the adherence of the patella in its dislocated position. Some operators prefer to preface the operation on the knee structures by osteotomy to correct the knock-knee, if that be present and considered one of the causative factors. That seems to be a wise choice; illustration of such a case is given (see Fig. 501). The osteotomy should not be too near the lower end of the femur but should be high enough to allow complete correction of the knock-knee without the making of a sharp angle near the joint and without incurring the risk of opening the joint. Grieg[2] is a firm advocate of osteotomy, as he believes the relaxed capsule has little to do with the tendency to luxation, while the knock-knee and its effect on the mechanism of extension have a great deal to do with it. The knock-knee corrected leads to a gradual change in the structures about the joint and improved muscle coördination, looking toward less chance for recurrence.

In simple cases where the ridge of the external condyle is of fair value, repair is made much as in the case of acute dislocation. A longitudinal incision down the inner anterior aspect of the joint is carefully opened to the fibrous portion of the joint capsule. An opening is made in this about one-half inch from the patellar edge, and this portion of the capsule is then dissected away from the inner or synovial layer of the capsule for an inch laterally from the middle line toward the inner condyle. This dissection is carried up some four inches above the patella level. With heavy catgut stitches the median edge of the opened capsule is imbricated beneath the outer flap as in taking a reef in the tissue, and the remaining loose portion of the outer flap is attached by a continuous stitch well over onto the patella area. This overlapping suture runs the whole length

[1] Chirurgische Operationslehre, 1907, 5th edition, p, 436.
[2] Edinburgh Med. Jour., July, 1914.

of the dissection, narrows the capsule on the inner side and holds the patella firmly in its position; the upper end of the incision is further strengthened by sutures placed in the vastus internus to narrow it.

This reefing operation may be supplemented by a plastic on the patellar tendon, or the latter can be used alone. Goldthwaite,[1] taking cognizance of the lateral insertion of the patellar tendon and its tendency to favor a pulling force out of the quadriceps in its contraction, describes an operation in which he splits the patellar tendon. The outer half of its insertion is divided from the tibial tubercle, carried behind the inner half by means of burrowing and reinserted on the median side of the tibia. Here a small nail or heavy absorbable sutures can be used to hold it. The leg is put in extension for several weeks to permit the reattachment of the tendon.

More recently Robertson[2] advances an operation for dislocation of the patella by the fashioning of a semilunar flap of skin and fascia from the medial and posterior surface of the knee back as far as the semitendinosus. The base of this flap dissected up crosses the patellar area and after the semitendinosus tendon is cut as low down toward its insertion as possible, the patellar tendon is split and a short portion is turned up to be sutured to the cut end of the semitendinosus. This gives the pull of the latter tendon to prevent the slipping laterally of the patella and the operation is finished by plicating the capsule as set forth above.

Another plastic has been suggested by Whitlock.[3] It consists in cutting off the tendon of the gracilis, swinging it forward and inserting it in a split in the patellar ligament. Up to the time of this writing I do not know of any other operators having done this, although Whitlock first performed this operation in 1909.

Long-standing or congenital cases require the most elaborate surgical intervention if the pathology is complicated. If the patient gets around with flexed legs as in Murphy's case, the first step must be to lengthen the hamstring tendons, either by plastic operation or gradual extension by weight and pulley. In these cases some luxation of the knee-joint is apt to be present, and the capsule is greatly changed from years of contraction and malposition. If the leg can be brought into extension by proper means, the problem of the patella can then be attempted. Usually these patellæ have formed an adventitious bursa beneath them in their new location, the capsular structures are firmly bound down about the joint, and the patella itself may be quite immovable. Lack of functional irritation has robbed the condylar ridges of the femur of much of their height, especially the outer one, which in this class of cases is decidedly weak. Simple plication, or imbrication of the capsule will do no good with these patients, and the patella must first be freed from its lateral position, if necessary by the splitting up of the quadriceps and patellar tendons laterally, high above the knee especially. If the patella can then be

[1] Boston Med. and Surg. Jour., 1904, cl, 169.
[2] Surg., Gynec. and Obst., April, 1912. [3] Loc. cit.

slung into position, it is wise to deepen the intercondyloid groove so that the external ridge may be a sure protection against recurrence. This the operator does by reflecting the joint covering and periosteum and cutting down the groove with a large curved chisel, afterward covering the denuded bone with the joint tissues and the subquadriceps bursa which have been swung back and over. The capsule is then plicated, and a happy result expected. Murphy reports a few of these operations and gives excellent illustrations of them.[1] In some of his cases the patellar tendon was also displaced inward and fixed to a position corresponding to a normal tubercle of the tibia.

Backward dislocations of the patella into the knee-joint are practically always treated by open operation. Reduction is very difficult by manipulation but may be tried by the flexing of the knee further and the forcing of the patella out by gravity or shaking. Traction on the patellar tendon by means of a hook passed subcutaneously may also be tried, but on account of the associated tears in the capsule and quadriceps insertion open operation is the best treatment. The patellar tendon may require division for the reduction of the bone. After it is freed all parts are carefully sutured, or if the nutrition of the bone and its surrounding tissues seem to be threatened, it can be removed completely and its place filled by a flap of the quadriceps turned down from above and sutured to the stump of the patellar tendon.

Prognosis.—Traumatic dislocations promptly reduced and kept quiet until the capsule and ligaments have healed give a good prognosis, except that the joint distention and scar may lead to relaxed structures and a tendency to recurrence. If operation is performed and careful closure of the tear made, the prognosis is very good. Dislocations due to muscular action deserve a more guarded prognosis on account of the presence of some of the predisposing anatomical causes.

Manipulative reduction and rest followed by the wearing of an elastic knee support or leather cap give a knee which makes walking possible, but does not permit full active use of the joint. Operative corrections by the methods mentioned promise a good prognosis for nearly full use and no recurrence.

Chronic recurrent dislocations are frequent, and few are cared for by the surgeon, because the patient learns to replace them when they occur, and the knee, getting accustomed to the trauma of the dislocation, has little reaction. Operation offers freedom from recurrence and the wearing of corrective caps and avoids the future weak, relaxed and uncertain joint. The congenital and bilateral acquired cases are difficult to prognosticate. The operation of deepening the intercondyloid groove offers a good prognosis, as all of the cases have made excellent recoveries.

[1] Clinics, iii, 82 and 151.

CHAPTER XXV.

FRACTURE OF THE BONES OF THE LEG.

TIBIA AND FIBULA.

THE spines of the tibia; the upper end of the tibia or both bones; separation of the upper epiphysis of one or both; separation of the tibial tubercle; the shaft of one or both bones; supramalleolar, one or both; separation of the lower epiphysis; malleolar fractures (Potts); lipping fractures of anterior or posterior border of the lower end of the tibia. The head of the fibula; shaft of the fibula; separation of the lower epiphysis.

Anatomy.—The tibia develops from three centres, one for each extremity, and one for the body or diaphysis (see Fig. 506 for the schematic plan). In the diaphysis, ossification begins in the centre and extends gradually toward the extremities. For the upper extremity a centre first manifests itself about birth and develops with the peculiar tongue-like projection for the tubercle, as shown in the figure, joining the shaft at twenty years of age. The lower epiphysis appears during the second year of life and joins the shaft at eighteen years. The tibia is the longest bone in the body next to the femur, and is the strongest. Its broad upper end is covered with a thin compacta and the body is composed of heavily trussed, cancellous bone, able to receive shock and weight. Near the junction of the middle and lower thirds the compacta becomes thickest, and the medullary canal is well developed; this is the weakest point in the bone from the standpoint of fracture, particularly fracture due to torsion and indirect violence.

The fibula likewise develops from three centres (Fig. 507). It is almost quadrilateral in shape for the whole length of its shaft; its upper end does not enter into the knee-joint formation, and if it is the sole bone broken, fractures in it, except for the twisting breaks at the lower extremity, are caused most frequently from direct violence.

The ligaments of the knee are important. They have been dwelt upon at some length in the chapter on Patellar Fracture and Dislocations. In considering the tibia, the most important are the patellar, internal and external lateral, the posterior capsular, and the two crucial ligaments, anterior and posterior. The internal lateral ligament passes from the internal condyle of the femur to just below the internal tuberosity of the tibia, with branches as described in another chapter, and most of the external lateral passes from the external condyle of the femur below to the head of the fibula, while

a second smaller portion passes back to join the posterior ligament limiting extension and bounding the popliteal surface of the joint.

Sprain fractures of the knee, like those of any joint, involve these ligaments and their insertions. The ligaments can be torn on the bone surfaces or avulsed at their insertion, and the injuries lead to much pain and disability, particularly because they are not recognized. With the advent of better roentgenographic technic they are more quickly discovered and are carefully immobilized to permit small loose shells of bone, the cause of irritation and pain, to become adherent. Lange[1] called attention to these osseous bits.

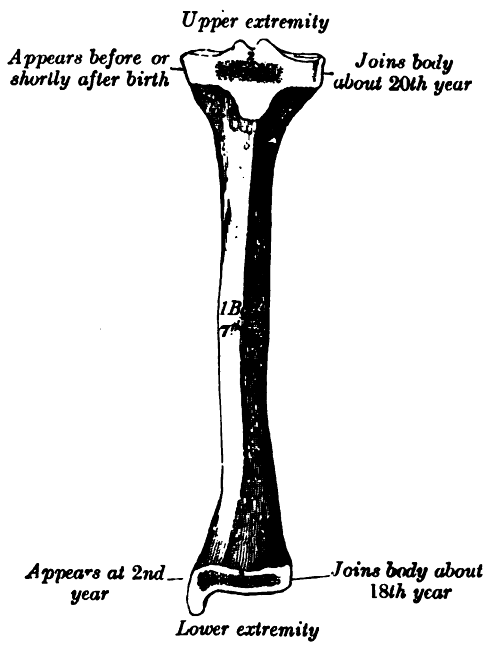


Fig. 506.—Plan of ossification of the tibia. From three centres. (Gray.)

Fig. 507. — Plan of ossification of the fibula. From three centres. (Gray.)

Fracture of the Tibial Spine (Intercondyloid Eminences).—On the head of the tibia are the anticular surfaces, which turn slightly upward and are separated by the two tubercles of the tibial spine. Between these two tubercles is found a groove which continues in both directions and broadens into the intercondyloid fossa. In the wider anterior intercondyloid fossa are attached the anterior crucial ligament and the anterior edges of the semilunar cartilages. In the posterior fossa, which slopes down and backward, the cartilages are attached to their respective sides of the spine, while the posterior crucial ligament is joined to the rounded surface posteriorly.

[1] Ann. of Surg., xlviii, 117.

From the anterior intercondyloid fossa the anterior crucial ligament passes backward, upward and outward, and is attached to the intercondylar fossa on the inner surface of the external condyle of the femur. The posterior crucial ligament extends from the tibial surface forward, upward, and inward behind the anterior ligament to become attached to the outer part of the anterior portion of the internal condyle of the femur. Consequently, as explained by Jones and Smith,[1] the anterior crucial ligament prevents the tibia from forward displacement on the femur when the knee is fully extended. On the other hand, the posterior crucial ligament, in complete flexion of the leg on the thigh, becomes tense and prevents the tibia from posterior displacements. Also because of this attachment both ligaments act as a check to inward rotation of the tibia, so that when the knee sustains injury and can be abnormally dropped back or pushed forward from the femur or rotated inward while in an extended position, injury to the crucial ligaments can be diagnosed. Knee-joints which are subject to a long-standing effusion or which are the seat of tabetic conditions, do not act normally. A fully extended knee will not permit forward displacement of the tibia provided the anterior crucial ligament is intact, and when fully flexed the tibia cannot be displaced backward if the posterior ligament is not torn across.

Roentgenographic study has proved that injuries to the tibial spine and crucial ligamentous damage are not so rare as was once believed. Godlee's paper in 1888, and Pringle's in 1907, were the earliest reference to the condition. Pringle found in the knee-joint of an amputated leg a loose piece of bone which was separated from the tibia and had attached to it the anterior crucial ligament and the external semilunar cartilage. This condition he believed was due to avulsion of the tibial spine on account of the strain on the ligament attached to it. Jones and Smith, however,[2] who found 17 cases in three years, believe some are caused by traction and others are chips of bone not included in the area of attachment of the anterior crucial ligament. The original skiagrams of some of these I had the pleasure of studying, and I have since seen 4 cases myself (Fig. 508). These authors say that a constant sign of fracture of the tibial spine is obstruction to full extension of the leg, which obstruction feels like a definite bony obstacle in contrast to the softer obstruction from displaced semilunar cartilages. They divide the injuries into three classes:

(1) Avulsion of the tibial spine or its internal tubercle.

(2) Fracture of the external tubercle of the spine.

(3) Combination of injury to the spine and tuberosity of the tibia.

(1) It requires great tension on the crucial ligament to cause avulsion of the tibial spine or its internal tubercle. Mayo Robson, Battle and Pringle (2) report cases caused by falls on the knee, or a catching of the leg in wheels. Violence great enough to rupture both crucial ligaments would cause dislocation of the knee. Pringle produced

[1] British Surg. Jour., i, No. 1. [2] Loc. cit.

rupture of the anterior ligament experimentally by fixing the pelvis, flexing the knee and abducting the leg with inward rotation. This tore the internal lateral ligament also, and with this addition the knee becomes flail-like. Kelly, of Liverpool, had a case in which both crucial ligaments were ruptured. The skin on the inner side of the knee was dimpled and the internal lateral ligament was not torn. In all cases of this avulsion the patient cannot fully extend the leg and on passive motion feels a bony obstruction. There is no abnormal

FIG. 508.—Fracture and avulsion of both tibial spines. There are concomitant fractures of the edge of the internal condyle of the femur and the internal tuberosity of the tibia. No operation was performed and the leg was useful after immobilization in extension.

mobility such as indicates crucial ligament rupture. The knee must be kept at rest for a long time, eight to sixteen weeks, and firm union of the tear can be expected. Examination after six weeks' immobilization shows little abnormal motility, although Pringle asserts that it can be demonstrated if anesthesia is given.

Rupture of the posterior crucial ligament is rare. As a rule it is torn at the femoral attachment. Jones cites a case reported by Pagenstecher.

(2) Fracture of the external tubercle of the tibial spine has no connection with injury to the crucial ligaments, as this smaller tubercle lies without their area of attachment. Experiments on the cadaver

in which the internal lateral ligament was divided, demonstrated that the inner margin of the external condyle of the femur would strike the spine without the division of the posterior ligament, so that it is believed that the tip of the external tubercle is nipped off by the sharp inner margin of the external condyle.

(3) Injury to the tibial spine, combined with rupture of the crucial ligaments, almost always accompanies dislocation of the knee and demands a long immobilization.

Treatment.—Cases of ruptured crucial ligament seen early after injury should be immobilized in a plaster dressing or a Thomas splint in complete extension for three or four months. In instances of fracture of the spine of the tibia, the leg should be placed in a position of extension by manipulation; then if the tibia cannot be pushed forward at the knee, and absence of laxity in the joint indicates that the crucial ligament is intact, the leg should be immobilized about eight weeks. After this it should be given careful passive motion and massage and increasing use.

Cases which are seen late and have not been diagnosed, in which the leg cannot be fully extended and there is much disability, can be cared for only by operative treatment. The leg is brought over the edge of the operating table and let hang as in the operation for the removal of loose semilunar cartilage. Incision is made in the midline on the front of the knee from an inch above the patella to the tuberosity of the tibia. The patella is sawed vertically and its ligament split longitudinally, after which the fatty tissue beneath is removed and the joint is well exposed. The obstructive mass of bone or callus which prevents extension is removed, and the joint is closed. In some very rare cases with much flexion deformity, arthrodesis or arthroplasty with shortening of the bones may be needed.

Tubercle of the Tibia.—Avulsion or fracture of the tubercle of the tibia[1] has been called Schlatter's sprain or Osgood-Schlatter disease, and has been defined as partial or complete separation of the anterior tubercle accompanied or not by tears in the joint capsule or rupture of some of the fibers of the quadriceps extensor muscle. The literature contains many isolated reports of one or more cases, and doubtless many have existed which have not been subjected to roentgenogram or which have been totally unrecognized and treated as joint injury or sprains. Blake found but two cases in the records of the Boston City Hospital and none at all in the Boston Children's Hospital. Referring to the figure of the ossification of the upper epiphysis of the tibia on page 734, it is clearly seen that the tongue-like projection which later becomes the tuberosity is part of the upper epiphysis. It may, however, have a separate centre of ossification. This projection into which the patellar tendon is inserted generally becomes completely ossified by the sixteenth year. If the tubercle is pulled out of place by action of the quadriceps before this ossification is complete, the

[1] Blake, Ann. of Surg., lviii, 207.

condition is a real avulsion and separation may be incomplete complete with capsular damage as mentioned (Fig. 509). This sep ration is incomplete because some of the fibers of the quadrice insertion are not inserted into the tubercle. Direct violence al may cause the immature tubercle to be displaced, and after ossific tion it causes more fractures of this point than muscular actio Schlatter's sprain in reality is never found after sixteen or sevente years of age in normal children, as it is a separation of the unossifi tubercle and is caused by intense muscular effort, as in running jumping. Separation after ossification involves a larger fragment bone, which may be pulled an inch or more out of place upward turned on its edge.

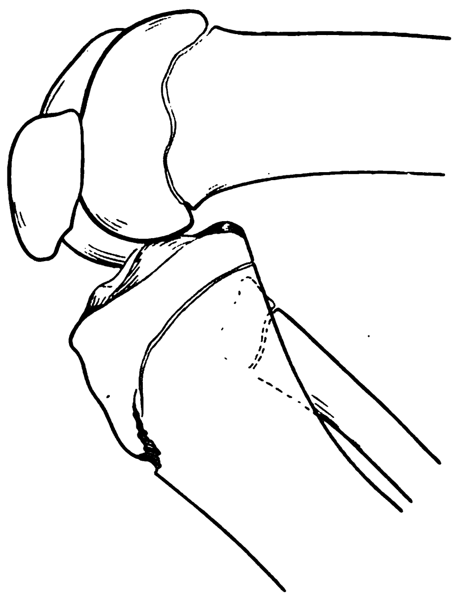


FIG. 509.—Incomplete separation of the tibial tubercle (Schlatter's sprain). The patellar tendon has just started the tubercle from its position by retraction. Note that the epiphyseal lines of the bones are not yet closed.

The symptoms and signs are well localized. There is inability to use the leg, extension being particularly poor and accompanied by pain in the region of the tubercle or in the joint. Extension is possible even if the tubercle is completely torn out, as the patellar tendon sends occasional bands of insertion to the sides of the tibia near the tubercle. The joint may become quickly distended if the capsule has been torn or an arthritis has resulted from any trauma. Examination demonstrates that the leg can be fully extended passively with little pain; acute tenderness in the tubercle region is felt when flexion is performed. Around the tubercle may be a lump, which is

slightly loose, and in moving which crepitus may be found. Corben[1] reported 2 cases, 1 with complete separation, the other just started out of place, and Connell[2] adds 2 cases in seventeen-year-old boys. In the first case the tubercle was torn completely off, and there was hemarthrosis of the knee, and in the second case the separation was caused by jumping on a vaulting horse. There were no knee changes.

Treatment in the cases with little separation demands that the leg be strapped in extension to relax the quadriceps femoris muscle. Three or four week's rest is needed with slowly increasing movements of flexion thereafter. Old cases, undiagnosed, are followed by much thickening and tenderness about the tubercle, and Jones[3] advises a linear incision with a chisel into the tubercle in the longitudinal axis for cure, which is complete in a few weeks.

Basseta[4] believes that some cases are Schlatter's disease, a clinical entity which is not connected with traumatic separation of the epiphysis of the tubercle and describes a case in which the clinical findings were manifested first in one leg and then the other with an interval of over a year caused by constant irritation, pull of the patellar tendon, and exaggerated ossification. There is probably a parosteal thickening, but if skiagrams can be made in the very early stages, undoubtedly some movement of this epiphysis out of place could be determined.

If the tubercle is completely torn off from the tibia or the upper epiphysis is started out of place in much of its length, open operation for replacement and holding by nail or wire is indicated (Fig. 510). Gibson[5] records a case nailed extracapsularly with an excellent result, and he refers to Erlmann, who had 2 cases, 1 operated and 1 treated by pressure bandage, and to Tilton, who had 2 cases, 1 wired and the other sutured in place by chromic gut with good results. Other instances are reported by Fowler[6] and Osgood.[7]

Fractures of the Upper End of the Tibia Alone or the Tibia and Fibula Together.—These fractures are caused by direct or indirect violence, the former accounting for many of the severely comminuted fractures of both bones which extend into the knee-joint. Such violence may come from direct blows as from a hammer, falls from a height, and in one severe case (Fig. 511) has come from a jump from the engine cab by an engineer to avoid certain collision, followed by his striking with his full weight below one knee against the steel rail of the opposite track. Indirect violence is exerted through a twisting of the leg with the thigh fixed, the leg being carried most frequently

[1] Practitioner, April, 1914.
[2] Practitioner, July, 1914, p. 146.
[3] Proc. Roy. Med. Soc., December, 1910.
[4] Arch. di Orthop., 1913, xxx, 305.
[5] Ann. of Surg., liii, 431.
[6] Internat. Jour. Surg., February, 1914, xxvii, No. 2.
[7] Boston Med. and Surg. Jour., 1903, cxlii, No. 5, p. 114; Overlook, Connecticut State Med. Jour., 1907, p. 288; Keyser, Sajous Annual, 1888, ii, 267; Ware, Ann. of Surg., November, 1904, p. 739; Winslow, Ann. of Surg., February, 1905; Poland, Traumatic Separation of Epiphysis, 1901; Mueller, Beitr. z. klin. Chir., November, 1887, p. 257; Landsberg, Centralbl. f. Chir., September 28, 1889.

in abduction. The line of fracture assumes any direction. Strictly transverse fractures are rare; oblique are common and usually involve the knee-joint or separate one tuberosity from the head and mushroom it down on to the shaft. If both tuberosities are crushed off, they separate near the middle of the joint. This fracture may involve the tibial spine and likewise be jammed down by impaction onto the shaft (see illustrative cases, Figs. 512 and 513).

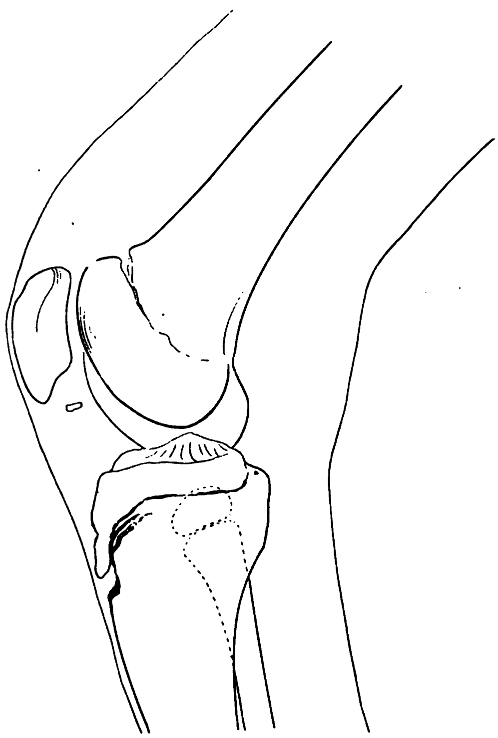


FIG 510.—A more complete type of separation of the tibial tubercle which has been lifted nearly half an inch out of place on the shaft. Planes of separation into the epiphyseal line and the body of the tibia are shown. There is also a small free body within the joint, probably a piece of avulsed bone.

FIG. 511.—Comminuted fracture of the upper end of the leg bones from direct violence received in a fall on a steel rail.

Direct violence acts in different ways, depending on the position of the leg. If there is a fall, or a blow strikes the tibia directly, this bone alone may be broken as described above; or if the violence is received by the patient while standing and supporting his weight, the line of force divides itself into two parts. One acts in a longitudinal direction, to resist which the upper end of the tibia was made so broad and of cancellous bone capable of taking up jars, and the other by

lateral pressure against the upper end of the bone which is supporting weight.

If the longitudinal force from the body weight is in preponderance, the bone splits. One or other tuberosity may come off, depending on which tuberosity receives the greater force, and the shaft is driven up between with accompanying injury to the fibula (Figs. 514 and 515). Should lateral pressure be great enough because of torsion or a giving of the leg or its retention against a solid object, with the

FIG. 512.—Fracture of the tibial head by direct violence. The fibula is not broken. Plane of fracture passes in two directions, one at right angles extending into the joint between the intercondyloid eminences.

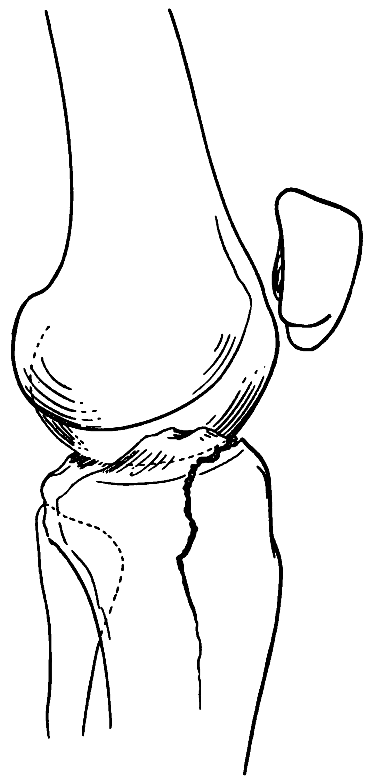


FIG. 513.—Linear plane of fracture of the upper end of the tibia opening into the knee-joint.

foot still bearing weight, the fibular head breaks off, the upper end of the tibia breaks across (Figs. 516 and 517), and there is more lateral displacement and not so much penetration of the shaft fragment into the upper fragment (Fig. 518). These same forces may cause fracture of the condyles of the femur and leave the tibia intact. Longitudinal fracture is uncommon, probably because the lines of the bone lamellæ spread laterally in the upper part of the bone and do not favor a direct splitting of the whole diaphysis, and the interposition of the epiphyseal area favors an end of the separation. A case

illustrating longitudinal fracture took its origin from low down in the shaft and passed upward for nearly the whole length of the bone.

Displacement is in accordance with the direction of fracture. Even transverse fractures with little separation show the tendency to impaction or mushrooming mentioned above. The body weight favors

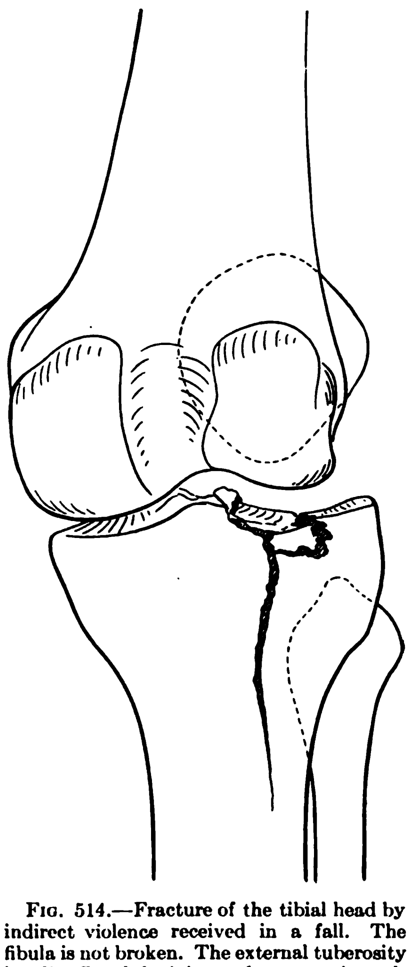


FIG. 514.—Fracture of the tibial head by indirect violence received in a fall. The fibula is not broken. The external tuberosity is split off and the joint surface comminuted. View looking at the knee from behind.

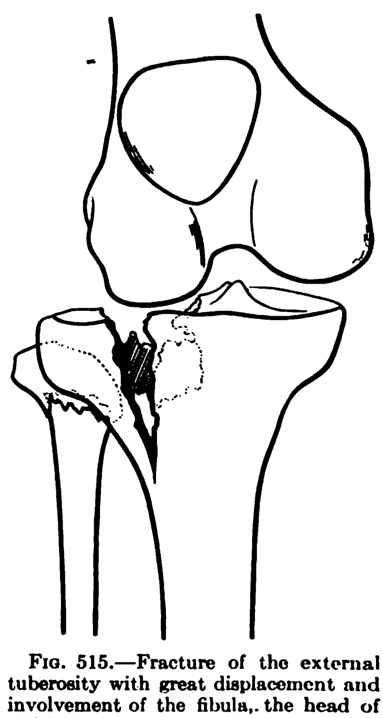


FIG. 515.—Fracture of the external tuberosity with great displacement and involvement of the fibula,. the head of which is mushroomed down onto the shaft. The knee appears in subluxation outward.

this jamming in of the fragments, and the abduction or rotative factor of the trauma aid it further. When one or both tuberosities are broken off or split, they tend to have lateral displacement with much broadening of the upper end of the bone. If fracture of the fibular head accompanies this, it may cause extensive widening of the bones below the knee. The popliteal vessels and tibial arteries are in this

field and subject to dangerous injury, which may end in gangrene and amputation. The joint always suffers an effusion or a hemarthrosis, the latter surely if the fracture extends into it. This joint swelling becomes the most prominent feature of the injury, masks the findings of the bone fracture, and may seriously impede circulation by its size. If pressure threatens to cause a bursting of the skin or to interfere with circulation, aseptic puncture can be done and aspiration of the joint performed.

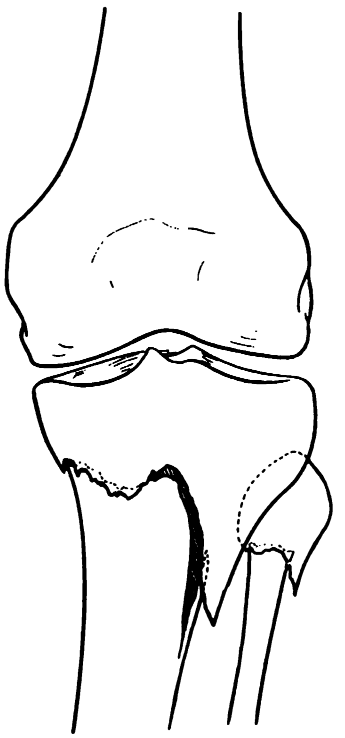


FIG. 516.—Fracture of both leg bones just below the knee by direct compressional violence. Oblique fracture. Body weight has impacted the fragments slightly.

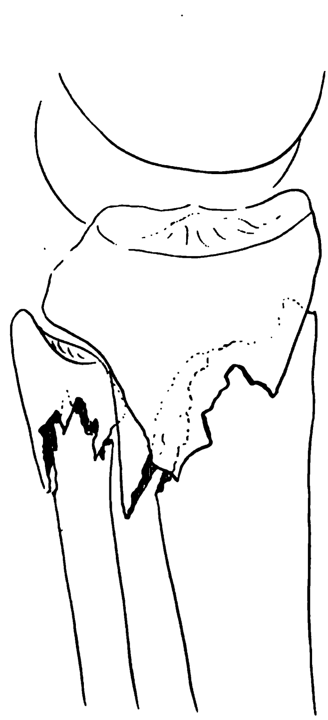


FIG. 517.—Oblique fracture of both leg bones caused by direct violence with some impaction caused by the body weight.

Diagnosis.—Diagnosis is based on the history, the loss of function, pain and tenderness, reaction and broadening of the joint, and change of axis or shortening of the leg. Careful palpation along the edge of the tibia discovers irregularity and pain at the site of fracture. If the fracture is not deeply impacted, crepitus and abnormal motility are present. Transverse fracture, high up near the joint, or epiphyseal separation must be distinguished from dislocations of the knee. The great rigidity, the pain on any attempt at motion, and the palpation

of the rounded tuberosities in dislocation out of their normal position, are helps.

Course and Prognosis.—The swelling of the knee or the interference with circulation may become matters of prime importance. Ice-bags should be applied at once, the joint put at rest in comfortable support until much of the reaction has subsided. If the fracture is impacted and the joint is not opened into and complete reduction is not obtained early, bony union proceeds with broadening below the knee, a slight shortening of the leg, and a slight axial deviation. Final results are fair but take from six months to a year to culminate; they may be aided by a lift on the sole of the shoe or other corrective methods. If the knee-joint is involved, or great effusion into it exists, the prognosis is always grave. A tuberosity broken off and displaced by a fracture plane into the joint unites in malposition, callus wanders into the joint, the long immobilization required leads to thickening and restriction of the synovial surface and the formation of adhesions. The final result may be complete ankylosis of the knee-joint with much broadening, the under surface of the patella becoming adherent to the femur. Suppuration of the joint is possible. The long relaxation of the ligaments from effusion and immobilization leads to a weakened joint in those joints not stiffened as a result of the trauma, and final function is much impaired. If active massage and motion treatment is persisted in after pain has left the knee, cases which seem to offer poor outlook often give a final result that is surprisingly good. Ten months or a year is not an unusually long time to wait to obtain good use.

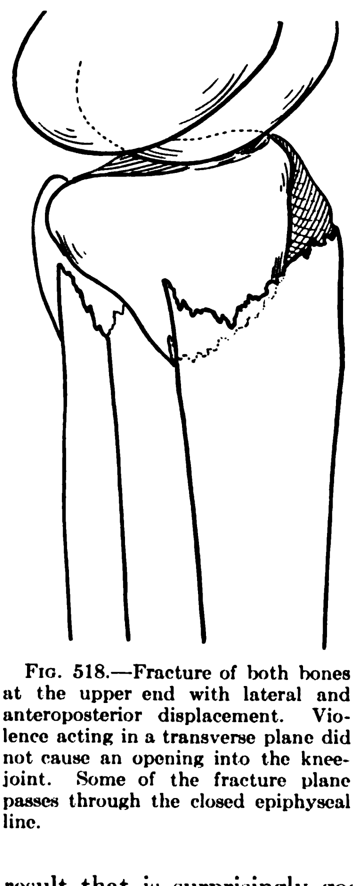


Fig. 518.—Fracture of both bones at the upper end with lateral and anteroposterior displacement. Violence acting in a transverse plane did not cause an opening into the knee-joint. Some of the fracture plane passes through the closed epiphyseal line.

Treatment.—Before the reaction to the trauma of fracture has thoroughly set in, reduction can be accomplished to a satisfactory degree in many cases by extension and counter-extension on leg and thigh with local pressure over the displaced fragments. Anesthesia should be employed in all cases. If the swelling and knee distention have already taken place before the surgeon sees the case, these require first care, as it is impossible to be sure of manipulative reduction in

their presence. It seems the best rule under these circumstances to elevate the foot of the bed and apply extension from below the knee with a weight of fifteen pounds, the line of traction being one which favors correct alignment of the axis of the whole limb. It must be recalled that in men the axes of the tibiæ are vertical to the ground surface, while in women there is slight bowing on account of broader pelves and more widely separated femora. Excellent results can be obtained by the early application of this traction, if it is steadily maintained and if sufficient weight is used to overcome the muscular action and thus allow the unlocking and correct alignment of the fragments. This also separates the synovial surfaces of the joints and tends to obviate intra-articular adhesions and further keeps the joint ligaments stretched, so that on attempts to resume use they have not so contracted as to interfere with function. In some impacted cases the mechanical extension gives relatively easy and immediate reduction, which is held by a split plaster cast or a wide posterior moulded splint.

Each case must be treated to meet the findings of the fracture with the following thoughts in mind:

(1) Avoidance of change in the tibial axis.

(2) Avoidance of adhesions in, and ankylosis of, the joint.

(3) The prevention of shortening, if possible.

A cast or splint which extends from the foot well up onto the thigh prevents axial displacements and disappointments after the permanent dressing is removed. This should be applied while the leg is in extension and under traction. The continuous extension by the Buck apparatus for a couple of weeks pulls many fractures into the joint to a good position and after that time a plaster encasement onto the thigh can replace it. After the third week the patient can become ambulatory, with crutches and a lift under the well foot to prevent the possibility of weight-bearing on the injured leg. If the joint is concerned, the rule following fracture into joints should be adhered to and the immobilization made at least 50 per cent. longer; in these cases immobilization should be employed eight weeks and then passive motion and massage can be begun gradually and never to a painful extent. After a year results are final in well-cared-for cases.

Rarely, on account of wide separation of the tuberosities or comminuted involvement of the joint, it seems wise to open these fractures and nail the fragments closely together. This is a dangerous proceeding to undertake while the hematoma is fresh and extends into the joint, for there is little resistance to infection, and if it is once started, the whole joint is soon involved. After time for subsidence and absorption of this blood is allowed, callus formation has proceeded and frequently little can be gained by attempts at nailing. Early manipulative reduction with steady heavy traction is by far the best method of treatment.

Open fractures of this character are very dangerous. Every effort is made to afford proper drainage and no chance for infection. The

leg is enclosed in copious dressings after thorough treatment with iodine and dressed with sterile gloves each time. If infection follows, counter-openings, and gutta-percha drains should be inserted from the dependent portion of the joint with avoidance of important structures. The early use of autogenous vaccines obtained from cultures of the pus, frequently gives prompt subsidence of the infection in the bone and joint and should be invoked in every case.

Separation of the Upper Epiphysis.—This injury is rare, and there are but few cases of the uncomplicated displacement on record. Poland collected 24 cases. This epiphysis unites with the shaft as late as the twenty-fourth year, and as early as the twentieth, and includes, as indicated in the diagram (Fig. 506), the whole articular surface of the tibia, the tuberosities and the tubercle, which sometimes has a separate centre of ossification arising about the eleventh year and persisting a year or two before fusing with the rest of the epiphysis. The cause is usually a violent twisting or wrenching of the leg and produces practically never more than a partial displacement. Most of the recorded cases are of movement forward of the epiphysis on the shaft, although the displacement is sometimes combined with lateral movement outward. Hutchinson[1] says that the separation at this epiphysis is rare, because the insertion of the internal lateral ligament, the ligamentum patellæ, and the semimembranosis tendon cover both the epiphysis and part of the diaphysis, and these ligaments are powerful connecting retainers of the epiphysis to the shaft.

Treatment.—Treatment consists in early complete reduction under anesthesia. The knee is flexed to relax the hamstring tendons, and then the tibia is pulled forward into position while counter-extension is made on the thigh above. As the separation is through the soft epiphyseal tissues, they hold themselves when reduced and do not tend to be displaced again. Results after reduction are excellent, and no trace of the fracture remains in a few months. If complete reduction is not accomplished, there is sharp angular deformity at the site of separation, and in the course of time the leg adapts itself to the change in the tibial axis enough to establish good function. After reduction no weight should be borne on the leg for from four to eight weeks; a moulded splint or a circular cast should be applied. After this is removed the leg should not be used until all tenderness has gone, and the patient should be particularly careful about climbing stairs to avoid stumbling or the pulling out of the tubercle that has been involved in the separation.[2]

Fractures of the Shaft in its Length, Including Supramalleolar Fractures.—The two causes of these fractures are direct and indirect violence. The former may be applied at any point in the shaft and results in fracture of one or both bones. Bardenheuer has said that when a force is applied against the long axis of a bone it resolves

[1] British Med. Jour., July 16, 1887.
[2] Walton, Fractures and Separated Epiphysis.

itself into two components, one on the convex and one on the concave side of the bone. The tibia or both bone fractures of the leg furnish the best example in their shafts of this mechanism and also of the mechanism of torsion or torsion combined with some flexion. Several distinct types can be attributed to direct violence, as illustrated in Figs. 519 and 520.

Fig. 519. — Transverse fracture of both leg bones caused by direct compressional violence. The broken out wedge-shaped piece is comminuted.

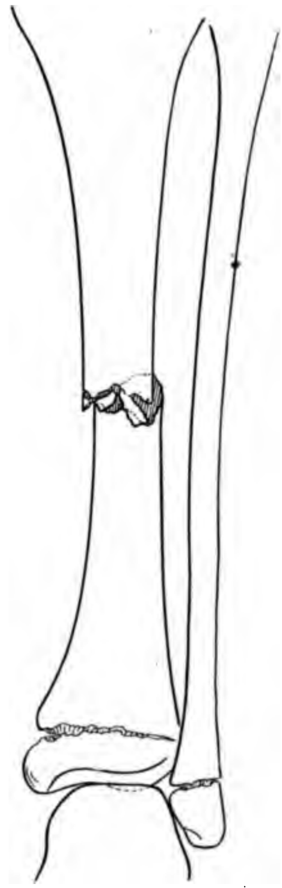


Fig. 520.—Transverse fracture of the tibial shaft with some separation of the lower epiphysis, caused by direct violence. Fibula unbroken.

These show that in complete fractures from direct violence or flexion fracture, the transverse separation is found only when the force is applied at right angles to the long axis of the bone. The lines of fracture diverge from the beginning of the bone separation on the convex side of the curve in flexion. They tend to run toward the concave side of the flexion in such a manner that a triangular or wedge-shaped piece of bone is burst out with its base toward the

concave side of the flexion. This broken-out piece may be comminuted. If the force of flexion or direct violence acts more slowly or less vigorously, only one of these divergent lines or fissures may become complete, so that an oblique fracture results (Figs. 521 and 522). Pure flexion fracture of the tibia is not the common finding. Such fracture is more often located in the lower third of the shaft where the cortex is thickened and the medullary cavity is best defined. Although it is true that pure flexion fracture requires violence applied at a right angle to avoid the influence of torsion, this type may be produced indirectly as well as directly. If two forces are applied to

Fig. 521.—Oblique fracture of the tibia with comminution of the small fragment. Fibula unharmed. Cause, direct violence.

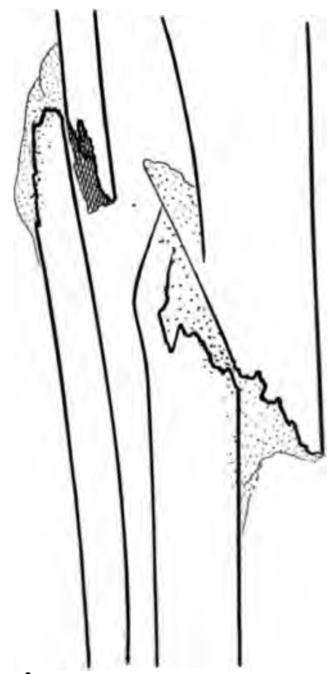


Fig. 522.—Oblique fracture of both bones, healed with deformity. Note the mass of callus between fragment ends where the periosteum was stripped up.

the leg on opposite sides and at a distance from each other, a flexion fracture results indirectly, or, should these opposing forces be on the same level, comminution of the shaft results, with longitudinal fissures, and if one force is just above the other, the result is transverse fracture with lateral displacement, called a shearing fracture (see chapter on Etiology and Mechanism).

Whether the fibula is also fractured depends largely on its elasticity. Fractures of the tibial shaft alone are more common in children, because in them the fibula is more elastic. In adults and the old because of greater rigidity, if the torsion continues the smaller bone

is generally broken at a higher level with a line similar to that of the tibial fracture. Should flexion enter into the mechanism, the fibula is likely to sustain a flexion fracture.

Torsion fractures of the tibia or of both bones result from torsional violence at either end of the limb, that is, with the foot and ankle fixed, the torsion coming from the trunk above as it is swung around, or the limb above is fixed and the twisting force is applied at the lower end. Spiral fractures are more common in the leg than any other part of the body. In young individuals, on account of a higher coefficiency of elasticity in the bones, the spirals of shaft fractures are steeper and longer (Fig. 523). It seems also true that, because *external* rotation of the mobile peripheral part of the leg is more common than internal rotation arising from the swinging of the trunk, spiral fractures of the right leg are left-handed, that is, the curve passes down as a staircase with a left-handed turn, and spiral fractures of the left leg are right-handed. The exceptions to this rule are those cases caused by internal rotation of the limb from the trunk swinging above. Consequently we expect the same type of fracture, whether the foot or lower leg is rotated violently outward on the fixed limb above, or whether the trunk rotates the proximal portion of the limb inward while the foot is fixed. In true oblique fracture caused by flexion the pointed ends of the fragments lie on opposite sides of the bone, as illustrated in the diagram modified from v. Bruns, but in torsion spiral fracture of the tibia the sharp ends are usually on the same side (the posterior surface) of the shaft, connected by a longitudinal line which runs down the anterior aspect of the shaft (Fig. 524).

Fig. 523.—Spiral fracture of the shaft in a young adult. Note the steep angle of the plane of separation.

Shaft fractures of the leg bones assume all the varieties of displacement. They are transverse, buckling, oblique, with and without overriding and rotation, comminuted, and in a large percentage involve both bones. Oblique fractures from compression when the fragments are completely separated are constantly rotated through a varying angle (Fig. 525). These fractures may be opened from within by the sharp points of bone, or in direct violence are frequently opened at the time of injury by the trauma. The nutrient artery may be broken off at its point of entrance or other arteries and nerves in the leg injured, but these complications are quite rare.

In the pathology of the healing, complications arise as follows: Adherence of tendons and muscles to the callus, shortening of the leg from incomplete reduction, change in the axis of the distal portion of the leg leading to an improper weight-bearing line and its complica-

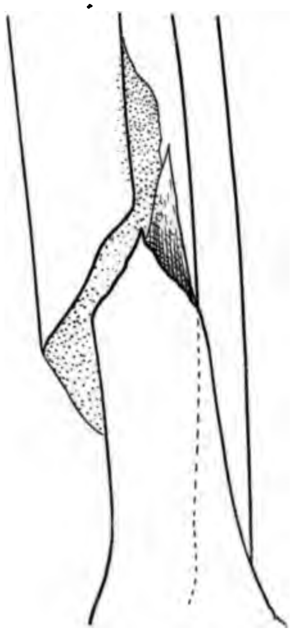


Fig. 524. — Spiral fracture of the shaft in a forty-year-old man. The spiral is rather abrupt. Callus of repair shown.

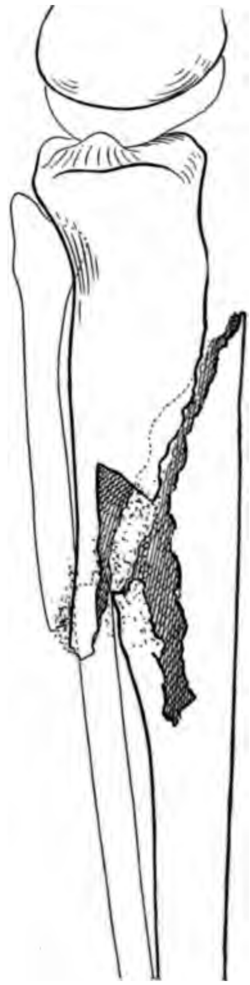


Fig. 525.—Long spiral fracture of both leg bones seen from the side. There is some overriding and anteroposterior displacement with angulation in the leg. This type may easily puncture the skin covering.

tions (Fig. 526). Excess callus is rare in the leg. Thickening of the leg with edema of the distal portion and interference with circulation arise from incomplete reduction. Delayed union, fibrous union, or non-union are more common in the leg than in any other part of the

body, in the author's experience, and yet with careful attempts at reduction these results do not happen in more than 3 per cent. of all cases.

Symptoms and Signs.—The position of these two bones beneath the superficial tissues makes diagnosis easy. Pain, change in the leg axis, swelling, and loss of function are constant findings. Crepitus is very frequently found, and the deformity is usually so apparent to the eye that measurements of the leg are not needed to verify overriding or shortening (Figs. 527 and 528). By passing the fingers down the crest of the tibia the surgeon can find the point of bony separation, or in incomplete fracture can locate the point of constant recurring tenderness. The same procedure along the shaft of the fibula gives positive findings in both bone fractures. Incomplete fractures, or the extent of radiating cracks, of triangular fragments, and of torsion fractures are shown clearly by roentgenogram.

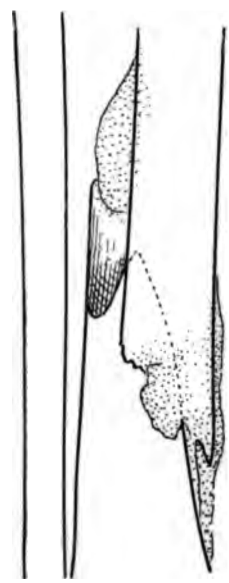


Fig. 526. — Healing fracture of the tibia. Deformity with overriding and callus development.

Treatment.—The spare covering of these two bones by the leg tissues, the strength of the muscles covering them, and the difficulty of maintaining prolonged extension make good results very difficult to obtain in treatment. It appears that no ideal treatment has yet been devised for oblique or torsion fractures involving the shaft of the tibia or both bones of the leg. Incomplete or fissure fractures, fractures of one bone with little displacement, transverse or shearing fractures are amenable to satisfactory treatment. Manipulation with extension under anesthesia suffices to give good reduction, and treatment should aim to fulfill these conditions previously mentioned:

(1) It should overcome axial deformity in the leg.

(2) Shortening should be avoided.

(3) Complications, such as delayed union, adherence of tendons, chronic swelling of the distal portion and loss of function should be guarded against.

In all types, except the oblique and torsion fractures, early proper reduction meets these requirements. If needed to overcome displacement the mechanical extension can be used and a circular cast or moulded splint applied, immobilizing both knee and ankle. Routine treatment consists in the placing of the leg in a comfortably padded fracture box or blanket splint, the application of ice for a few days until the swelling is gone, and then reduction. Kanavel[1] has suggested a combined board and blanket splint which is easily made and

[1] Surg., Gynec. and Obst., June, 1906.

by means of the piece nailed across the ends of the longitudinal board (see Figs. 529 and 530), holds the leg steadily up from sagging into the bed. All circular casts should be cut open and rebandaged at the time of application. Four to six weeks will give good union. After

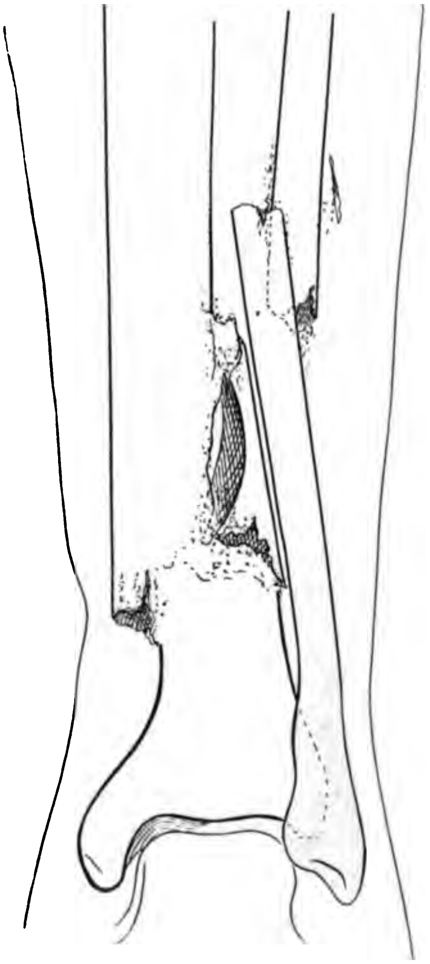


FIG. 527.—A common type of shaft fracture of both bones. The fibula is broken on a higher level and a piece is split off the tibia so that there is lateral and angular displacement. Compression combined with torsion was the cause.

FIG. 528.—Compression fracture of both bones, the fibula breaking after the tibia. Note the callus and the opportunity for ugly deformity if better reduction is not made.

three weeks the leg can be removed daily from the cast for massage and passive motion.

Tenotomy of the calcaneus tendon has been suggested as a means of overcoming the contraction of the soleus and gastrocnemius muscles.

This I have done in a few cases and been able to secure easier reduction, but the cases did not turn out well otherwise, and it is a debatable question whether the leg ever regains full power when this tendon is cut. Wharton[1] considers this measure good practice in irreducible cases. G. G. Davis, discussing this point, recalls the anatomical

FIG. 529.—Kanavel's board and blanket splint for leg fractures. Boards approximated to the leg which lies in the blanket swing.

and mechanical facts of the leg muscles division into four groups: first, the anterior set, composed of the anterior tibial, the extensor hallucis and the extensor communis digitorum; second, the posterior set, the tibialis posticus, the flexors of the toes and great toe; third,

FIG. 530.—Blanket and board splint with cross-piece nailed on end. Reinforcing bandages about the splint are not shown in the picture. (Courtesy of Dr. Kanavel.)

the three abductors, the peronei which do not influence flexion and extension to any great extent; and lastly the calf muscles, the gastrocnemius, soleus and plantaris, which really have nothing to oppose

[1] Ann. of Surg., lii, 276.

them. If the calcaneus tendon is cut, we should look for a muscle balance in the leg, but, as mentioned, the tenotomy may do permanent harm to the calf muscles. Davis suggests that to get rid of their action the leg should be placed in Pott's position, *i. e.*, flexed on its outside, following which reduction may be much easier (Figs. 531 and 532).

Mechanical extension with force of 100 to 150 pounds applied by the portable apparatus, or while the patient is on the fracture table,

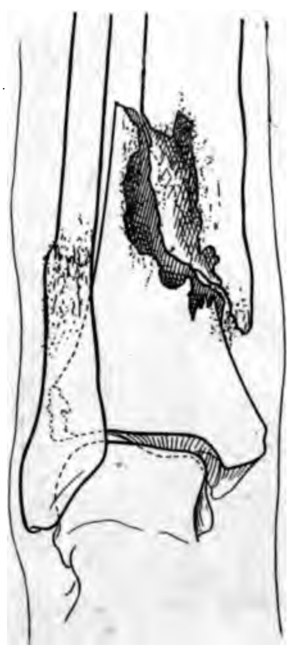


Fig. 531.—A good result of manipulative reduction and plaster encasement. The weight-bearing line of the tibia is nearly correct.

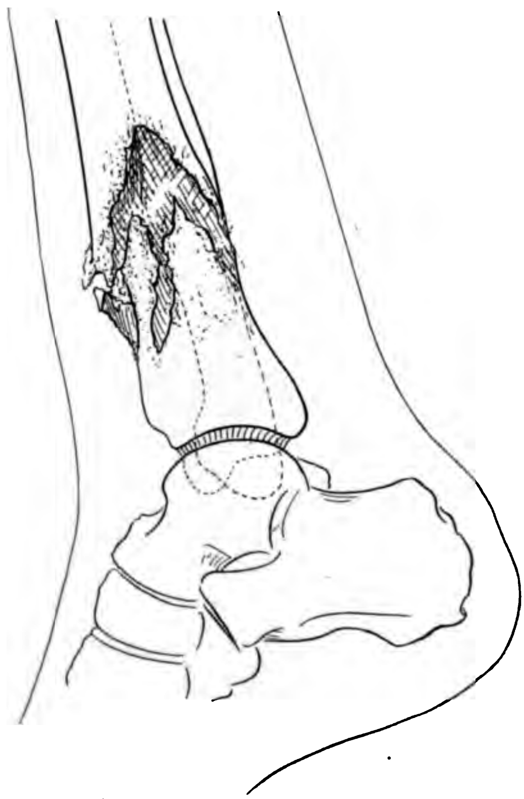


Fig. 532.—Lateral view of Fig. 531. There is practically no anteroposterior angular deformity nor much shortening.

gives a happy result, if it is maintained until the circular cast has hardened. This must be applied over copious padding, and if the primary fracture reaction has subsided in the leg the cast may not have to be cut open; but the toes must be watched for coldness and lack of capillary circulation, and if pain or numbness appear, the cast is split open at once. I have had no pressure sores or untoward results in cases treated in the last four years, but do frequently find one-fourth to three-eighths inch shortening. A few cases treated by this

method are reported by Peckham.[1] Other means of obtaining length and lessening deformity consist in applying the plaster first to the foot and leg above, leaving the site of fracture open. Extension is then applied over the foot portion to lengthen the leg, the fragments are manipulated into place and held there while additional plaster is applied outside of the two parts already on the leg to make one continuous cast. This is open to the objection that one cannot be sure of the effect of the pressure on the casted foot. The site of fracture tends to swell and become edematous and may interfere with

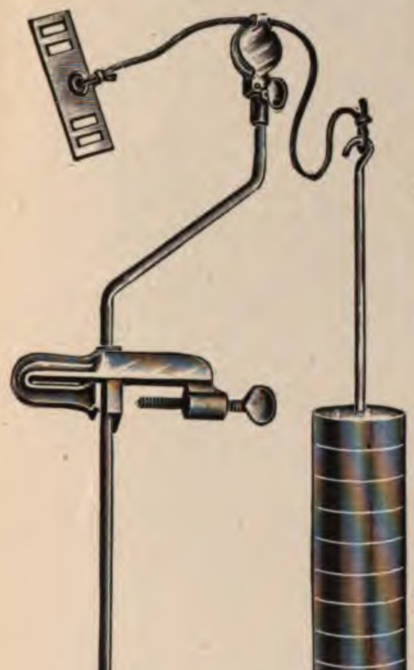


Fig. 533. — Swenson's adjustable apparatus for continuous leg extension.

Fig. 534.—Swenson's extension apparatus applied to Buck's extension.

distal circulation. If it is necessary to split the cast, the plaster frequently cracks apart and the extension force is lost.

Oblique and torsion fractures may be happily reduced by means of extension, but the slightest relaxation of the extending force permits a sliding past of the oblique surfaces so that the deformity recurs (Figs. 533 and 534). This is difficult to avoid by any means. The use of mechanical extension, and the application of a plaster encasement which is allowed to harden before the extension is loosened may

[1] Jour. Am. Med. Assn., lxiv, No. 4, p. 308.

be successful. A Thomas splint with continuous traction or an extension applied by adhesive from a point below the fracture, may be useful, but though good axial replacement may be thus obtained, results in nine-tenths of the cases manifest some shortening or loss of function arising from tendon interference or chronic swelling. No weight should be borne on oblique fractures until the callus is very firm, ten to twelve weeks, and six to eight months is not too much disability after severe grades of this injury.

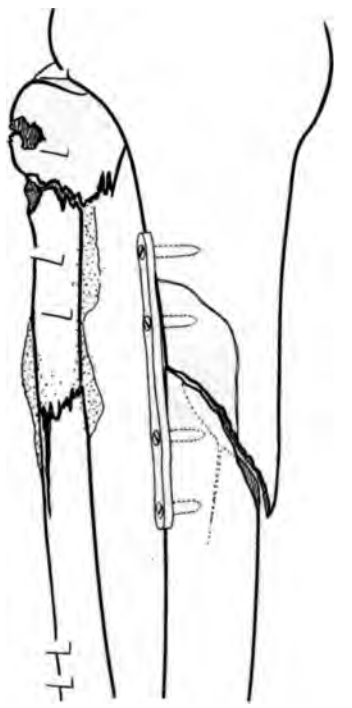


Fig. 535.—Plated reduction of spiral fracture of the tibia, applied on lateral surface.

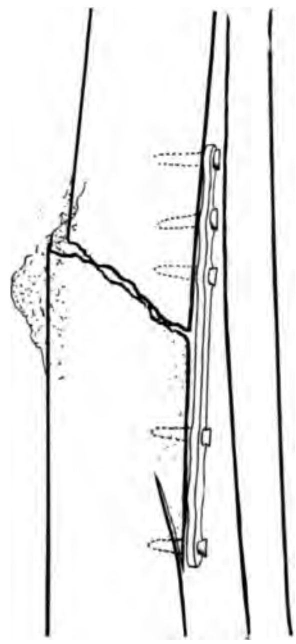


Fig. 536.—Plated reduction of an oblique fracture of the tibia. Note that the plate is not set on the anterior surface of the bone just beneath the incision.

Operative Treatment.—The statement concerning ideal treatment and results made in the preceding paragraph finds application here. The best reductions and maintenance are obtained by the Lane plate. The scant covering of the leg, the difficulty of approximating and tightly closing the skin after the operation of plating favor infections in these opened legs. Plates should be large and with sufficient screws to hold the leg firmly, and it is the best practice to apply them on the lateral aspect of the bone where they can be covered by the thick muscles, as the tibialis anticus, and not lie immediately beneath the incision and its closure (Figs. 535, 536, 537, and 538). If infection is late and of mild character, or the operator chooses to ignore it alto-

gether in his treatment, preferring to get good approximation and remove his plate at the earliest opportunity after union, this treatment may be the best of all, though two operations are needed and the possibility of chronic osteomyelitis exists. I have seen many

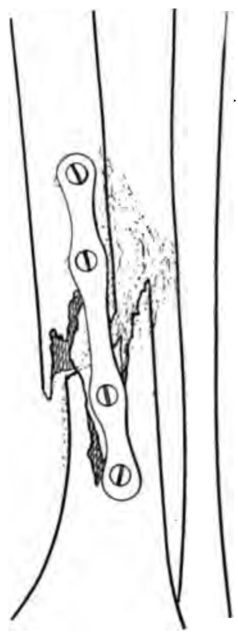


FIG. 537. — End-result in a plated fracture of the tibia. The plate was not long enough and pulled out the compacta of the lower fragment, permitting some slipping displacement. Good callus nevertheless.

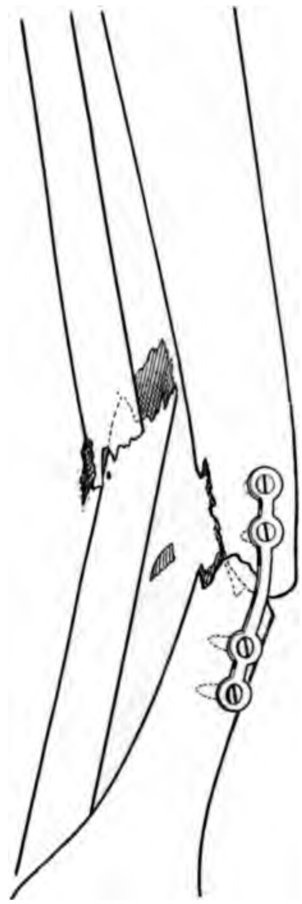


FIG. 538.—An example of inefficient plating in fracture of both leg bones. The plate was too short and probably there was insufficient external support applied for too short a period so that the plate had to bear the stress of weight-bearing before bony union.

cases of disability of one or two years following infection about Lane plates applied on the tibia, especially in the lower third of the bone. The time of removal in most of these cases had not been delayed. Recently I resected one-third of the tibial shaft subperiosteally to remove necrotic and ununited bone one year after plating, the plate

having been taken out two months after insertion, fragments of bone, some containing screw holes, having been discharged in the meantime.

One case which was of interest followed a gunshot fracture of the tibia. Some weeks after the original injury a surgeon opened the leg and put it in good alignment by the application of an eight-screw plate. A good recovery with an aseptic wound and good function resulted. Thirteen months later the patient came into my hands with some soreness in the shin and a small sinus developing. The plate was a source of irritation, infection had started about it, and I had to remove it. In doing so I observed that the bone at the lower end had grown around the plate firmly. It had to be chiseled loose. Prompt recovery from infection and disability resulted. Another case operated in the same week had been plated some three months before with apparent aseptic result, but had little function on account of the short time since fracture. The man came to me with a sinus similar to that of the preceding case. This plate was removed and the wound left open for drainage, but the infection in this tibia, although apparently no more extensive than in the first case mentioned, took nearly nine months to quiet down and close. These two examples were in men in different vocations and with different personal care and resistance. The one who carried the plate nearly a year was a well-nourished business man of excellent habits who had no focal infection that could be discovered; the other was a railroad switchman with many unhygienic habits and infected teeth, was not well nourished nor of high resistance. Such factors as these should be considered in selecting cases for internal splints, in the leg particularly. When infection first manifests itself the plate should be removed and the bone not disturbed. It is wise to prepare an autogenous vaccine from cultures taken at the time of operation.

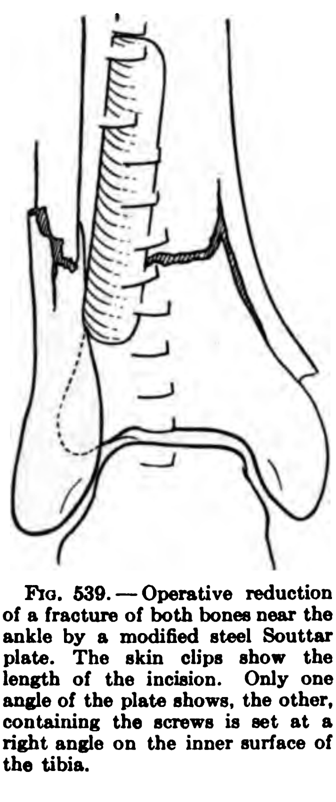


FIG. 539. — Operative reduction of a fracture of both bones near the ankle by a modified steel Souttar plate. The skin clips show the length of the incision. Only one angle of the plate shows, the other, containing the screws is set at a right angle on the inner surface of the tibia.

Souttar[1] suggested a right angle plate built like a T steel beam with one arm lacking, which appears L-shaped on cross section. I have used a slightly-modified type of the plates on lower third tibia fractures and like them very much (Fig. 539). The fragments are brought

[1] Ann. of Surg., November, 1913.

into apposition by open operation, and by means of a circular saw a slot is cut into them, crossing the line of fracture in a longitudinal direction. Into this slot the right-angled wing of the plate is slipped and lightly pounded until the other wing, which I have had made with a slight curve, fits down flatly onto the outer surface of the shaft. This portion has screw holes in it, and when the screws are inserted the plate is found clamped down very firmly to both fragments, the slight curve mentioned allowing the outer tip to bite down against the bone and give great security. The wing buried in the bone tissue prevents lateral movement, the wing fastened along the shaft surface prevents motion in the anteroposterior plane as would a Lane plate, and the whole gives perfect and very firm apposition.

Wires are frequently used to hold the fragments together. Silver or phosphor-bronze wires inserted through holes made in the cortex have little value in holding these fragments together unless the fracture is distinctly transverse. If it can be reduced, even by open operation, simple reduction without the wires often holds, and it is better to omit the foreign body. A more favorable method is to wrap firmly several strands of phosphor-bronze wires around spiral fragments to hold them together. Strauss[1] has suggested the use of a filigree of woven strands of catgut applied around the bone to hold it in position.

Other valuable methods are those using external clamps or rods which penetrate into the fragments and bring them into line. Freeman[2] advocated their use through small skin incisions, fixation clamps or sterilized plaster of Paris holding the rods in position of good bone alignment (see chapter on Operative Treatment). Sabotte's and Parkhill's clamps are essentially the same, but Sabotte has given up their use except in cases of infected open fractures.

The nail extension in accordance with Steinmann's method is also used in the leg. Lyle[3] presented 3 cases so treated, 2 of which were of both bones of the leg. One was an open comminuted fracture which was treated by the nail extension for nineteen days and then put in a plaster encasement; the other was an infected comminuted open fracture treated by this extension for forty-seven days. Woodward[4] is enthusiastic over this method and finds that the anatomical results are all that could be desired (see general chapter on Treatment for Hackenbruck's method).

Comments on Steinmann's Nail Extension.—The disadvantages belonging to this method may be enumerated as follows:

Infection in the nail tract, necrosis of the skin of the heel, and osteomyelitis or other sequences. By adhering to a strict asepsis in operating, using a steel nail with the end pointed, and plastering over the wounds with collodion dressings the operator can avoid much trouble. In practice I use a smooth-polished, steel rod, which I obtain in two-foot sections. A piece sufficiently long is cut off and

[1] Surg., Gynec. and Obst., xix, No. 3, p. 410. [2] Ann. of Surg., liv, 381.
[3] Ann. of Surg., lx, 397. [4] Practitioner, London, 1914, xcii, 360.

one end bluntly pointed with a file. The point for insertion is selected on the outer side of the heel about the middle of the bone, the skin

FIG. 540.—Wire loop around nail passed through the calcaneus. Rope attached for extension.

drawn down a bit and an incision about three-eighths of an inch long made with a sharp scalpel down to the bone. This opening is retracted

FIG. 541.—Same foot as preceding figure.

and the nail driven through the calcaneus exactly parallel to the sole of the foot. As the nail point arrives at the inner side of the foot a

small incision over the oncoming point is made by the assistant, while the operator drives the nail on through, leaving an equal projection on either side. The collodion dressings are at once applied, followed by sterile dressings and bandage. Outside of this dressing the two nail ends appear.

Heavy copper or picture wire is used as a loop over the ends to harness the extension (see Figs. 540 and 541). To prevent this from slipping off, a shorter loop is applied to hold the two ends together across the sole like a stirrup. Sufficient weight, at least fifteen pounds in an adult, must be applied to overcome shortening. The leg is bol-

Fig. 542.—Patient's foot with nail extension and weight applied.

Fig. 543.—A spiral fracture of both bones of the leg treated by nail extension. Picture taken the day leg was removed from the cast which had been applied when the nail was removed twenty-one days after insertion.

stered on a padded board held in position by narrow sand-bags laterally, and frequent inspection is made that the attendant may be assured that everything is in position and that the weight is pulling. The foot of the bed should be elevated (see Figs. 542 and 543).

Overcorrection can rarely occur. The formation of a fistula is generally caused by too long maintenance of the extension, errors in technic of insertion, or of asepsis of withdrawal. The smooth rod gives little difficulty. The cases I have treated by this method gave no

rise in temperature. Spiegel[1] discusses 18 cases, 14 of which were for leg fractures. Fistulæ developed 5 times in 8 cases, necrosis (bedsore) was present in 8 cases, requiring an average of nineteen days to heal and furnishing a chance for infection. Swelling in the ankle-joint may result during or after the extension, just as after mechanical extension and the application of plaster encasements, but ankle stiffness caused by nail extension in the foot yields to treatment more readily than stiffness caused by plaster immobilization. In Spiegel's cases the nail broke three times, I believe because it was of too small size. Other complications, as the nail cutting through the bone, and healing of the fracture with deformity or knock-knee, arise from technical errors in the size of the nail and insufficient postoperative care of the maintenance of position.

Other modifications have been made for this extension by Nové-Josserand, and Rendu and Michel.[2] They have adopted a sort of plaster breeches, using the pelvis and sound thigh which are attached to the head of the bed by straps for counter-extension. This method is applicable to children who cannot be restrained and are not old enough to realize the importance of holding the leg in position.

Waegner[3] made a report on 70 cases of fracture treated by nail extension. He contrasts his cases with Körber's 70 cases reported in 1911.[4] Twenty-four of Körber's cases suppurated, 9 lightly; 12 had fistulæ. Waegner's 70 cases were treated with no infection at all. In 11 of them he obtained a thick drop of secretion after the nail was removed. Cultures made of this secretion showed Staphylococcus albus 4 times, sarcinæ alba 5 times, and no culture twice. There were no complications, as the patients were all reactionless and 59 of them had perfectly dry wounds. He emphasizes the necessity of considering this method a surgical one, to be performed with surgical asepsis, and in surgical surroundings, especially in connection with the care of foot and the removal of the nail.

Gelinsky[5] uses a wire extension from the heel, but he does not bore through the calcaneus. He prefers to put the wire through the insertion of the tendo Achilles, avoiding vessels and nerves. The extension is brought out over a small splint on the sole of the foot which is attached by adhesive plaster. An extension line to the weight is also applied to the forefoot, so that each part of the foot bears one-half of the force, and the line of traction corresponds to the leg axis. This application, he believes, is the only perfect and safe method of applying extension to the foot in malleolar and supramalleolar fractures (see description under Calcaneus Fractures).

Very satisfactory results are obtained by the intramedullary splint of autogenous bone. This should be firm enough in the medullary cavity to hold the fragments in position, and is rather difficult to insert

[1] Disser. Berlin, 1913, Accidents in Nail Extension. [2] Revue d'Orthop., 1913, v, 487.
[3] Verhandl. d. deutsch. Gesselsch. f. Chir., Berlin, 1914, xliii, i Teil, 201–3.
[4] Münch. med. Wchnschr.
[5] Zentralbl. f. Chir., Leipzig, xli, No. 34; also Zentralbl. f. Chir., Leipzig, 1913, p. 812.

when the tibia alone is broken, unless the interosseous ligament is cut through for a short distance to allow the fragments to be turned out of the wound (Fig. 544). Good alignment can always be obtained by this method, though some shortening may persist as the fragments tend to slip past each other on account of their obliquity. Ivory screws or nails, wire nails and metal screws are useful in selected cases, depending largely on the operator's skill and custom (Figs. 545, 546, and 547).

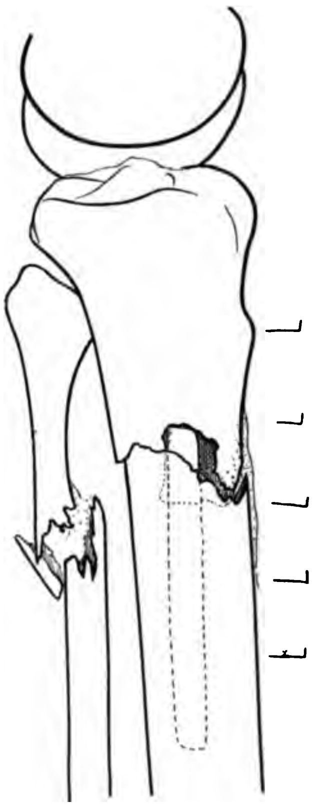


FIG. 544. — Fracture of both bones treated by an intramedullary peg. The alignment is good. Skin clips on skin edge.

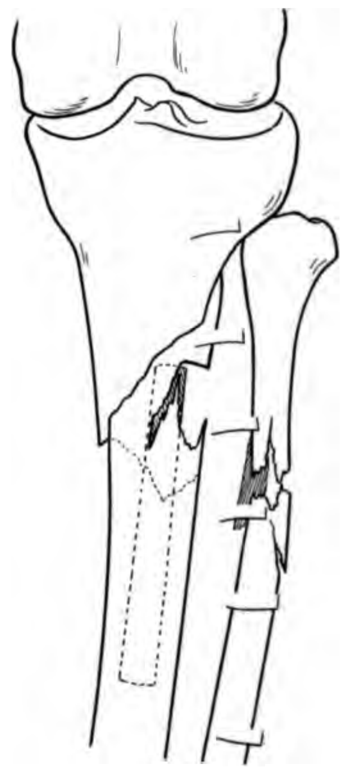


FIG. 545.—Anteroposterior view of the preceding figure. A long peg is necessary to give stability to this repair.

Open fractures arising from the causative violence or from fragment penetration are treated in accordance with the instructions for those cases in the general chapter on Treatment. Bryant[1] advocates the immediate application of a plaster encasement about these legs after the limb is shaved and the wound protected with gutta-percha. The cast is then cut open over the wound and the edges of the plaster are

[1] Tr. Am. Surg. Assn., 1912, xxx.

protected completely by gutta-percha to prevent soiling and to allow drainage and dressing. The limb is swung up in elastic suspension by rubber bands. The same result is accomplished by the use of an interrupted cast bound together by U-shaped bands of metal over the open wound (see Fig. 548).

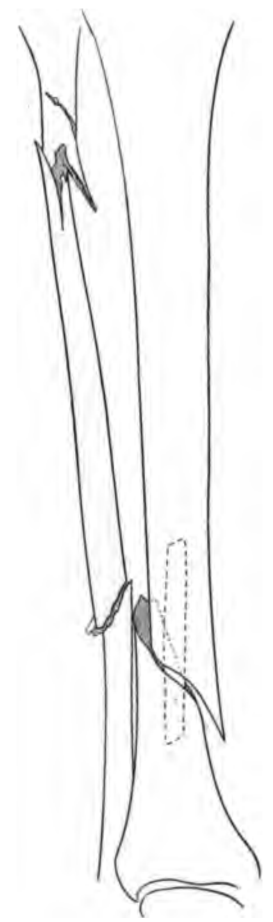


Fig. 546.—Repair of spiral fracture of the shaft by intramedullary peg. This postoperative picture shows a slight overriding, but the clinical result was perfect.

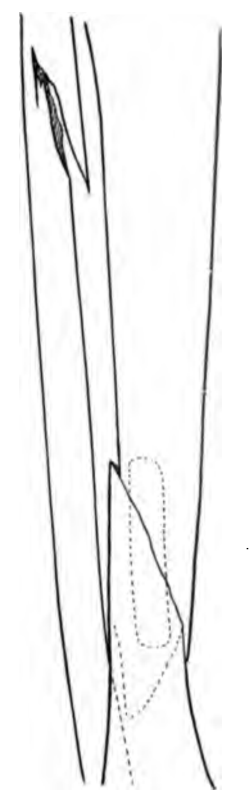


Fig. 547.—Repair of spiral fracture by intramedullary bone splint. Note that some overriding persists.

The *complications* of delayed and non-union are frequent in the shaft of these bones, especially in the lower part. The easiest method of treatment is for the surgeon to put on a firm plaster encasement which will allow the patient to become ambulatory and to bear a little weight on the foot as he gets about with crutches. If this fails, the ends of the fragments may be drilled aseptically or a regular open operation

performed. Intramedullary autogenous bone splinting is the best treatment, and must be supplemented by freshening of the fragment ends. An inlay graft has also been advocated by some operators (Fig. 549).

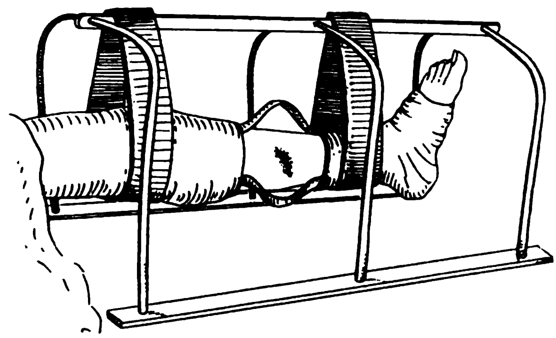


FIG. 548.—Interrupted cast for open fracture of the leg. Firmness assured by bent iron bands laid into the plaster. Whole foot swung up to facilitate dressing.

Henderson[1] suggests the cutting of a long, bevelled slot running into both fragments. From one side a longer piece is cut; that is taken out and inserted into the equivalent slot of the shorter fragment and bridges across the site of fracture, while the shorter fragment removed from the slot fills in the remaining deficiency (Fig. 550). Albee[2] also uses this method. It works admirably in simple cases of non-union with little displacement; in fresher fractures the inlay has less holding power and needs wires or accessory nails for maintaining the position of the splint and fragments. Lyle[3] records a case of both

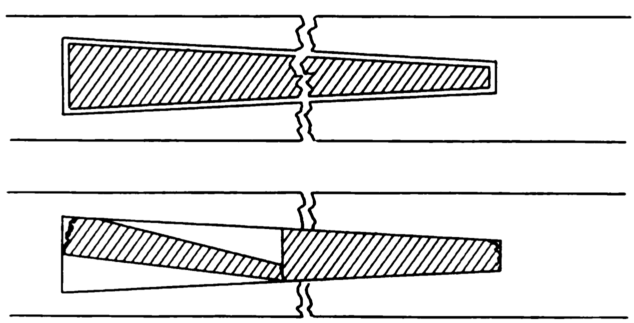


FIG. 549.—Diagrammatic representation of Gallies bone wedging. The wedge-shaped pieces are reversed after removal, the operator taking pains to be sure that one piece is longer than the other so that it will overlap the fracture plane when transposed.

bone fracture of the lower third of the leg ununited after three and a half months, which was then treated by Bier's method. He injected 20 to 30 c.c. of the patient's own blood around the bones every six

[1] Ann. of Surg., lix, 486.
[2] Am. Jour. Surg., 1914.
[3] Ann. of Surg., lvii, 284.

days, using sterile albolene to prevent clotting, and after the eighth injection obtained union. It is difficult to decide whether the time

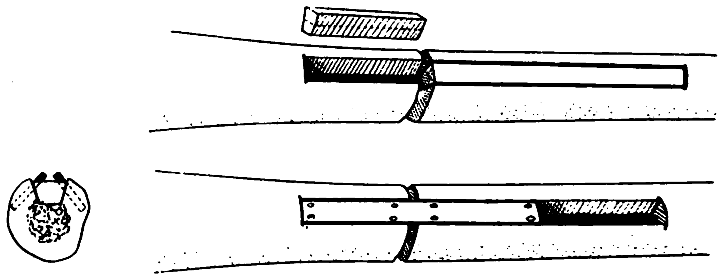
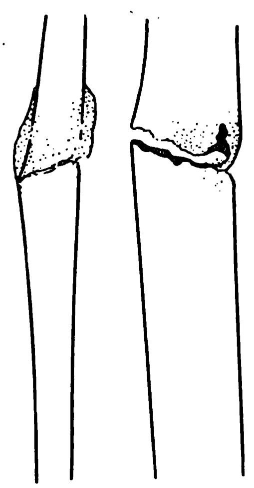
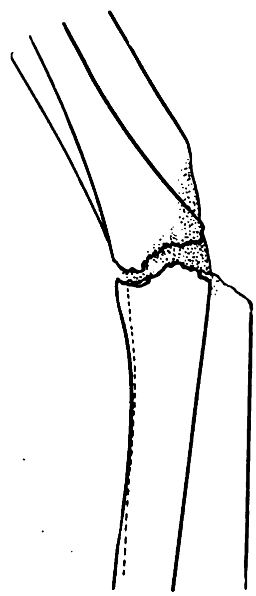


Fig. 550.—Albee's method of inlay bone graft. Small bone dowels hold the inlay in place.

element, the irritation of the needle, the blood, or the albolene was the main factor in producing union, but these elements coupled with patience are well worth trial (Figs. 551, 552, 553, 554, and 555).





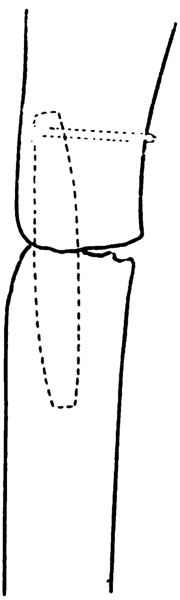


Fig. 551 Fig. 552 Fig. 553

Fig. 551.—Ununited fracture of the tibia of two years' standing. The leg has a false point of motion in its middle and was held in flexion from muscular contraction.

Fig. 552.—Side view of Fig. 551, showing the angularity of the leg.

Fig. 553.—Repair of ununited fracture of the tibia by an inlay graft after fastening the ends of fragments. A small nail in upper end of graft to hold it in place.

Prognosis.—The *prognosis* of leg fractures involving the shaft is in most cases hopeful. Some shortening is present in 70 per cent. of

cases; this is compensated for by an additional lift or two on the sole of the shoe. Edema of the leg, venous stasis below the fracture, and

FIG. 554.—Inlay graft in ununited fracture.

FIG. 555.—End-result of this ununited fracture. There was an inch shortening of the leg easily overcome by a lift on the sole.

FIG. 556.—Backward displacement in epiphyseal separation of the lower end of the tibia. This type of fracture is easily mistaken for posterior dislocation of the tibiotarsal joint.

pain may be present for many weeks. Function usually improves rapidly after use is attempted, provided the callus is firm and the

alignment is good. The outlook for younger individuals is brigh than for those in later life.

Separation of the Lower Epiphysis.—This happens more frequen than separation of the upper epiphysis and is caused by twists of t foot and other indirect violence, as in falls, or by forced dorsal plantar flexion of the foot with a continuation of the force in a late or shearing manner. As the cause always contains some torsion for it is a common finding to have a spiral split running into the shaft the bone. This is not a long plane of separation and is usually of t outer surface, *i. e.*, next to the fibula, as most of the torsions are that direction. When the epiphysis is displaced backward (as in F 556) the posterior surface of the diaphysis may be split off. Cotto in 1908, found that the records of the Massachusetts General H

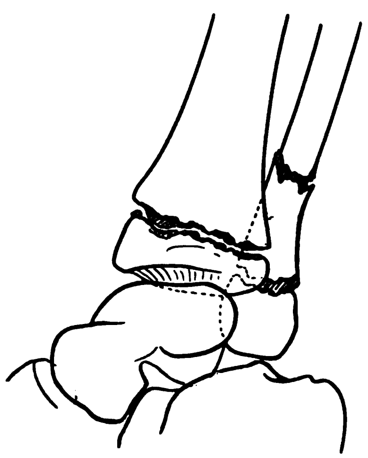


FIG. 557.—Epiphyseal separation of both leg bones at the lower end accompanied by a second fracture of the fibula a little higher.

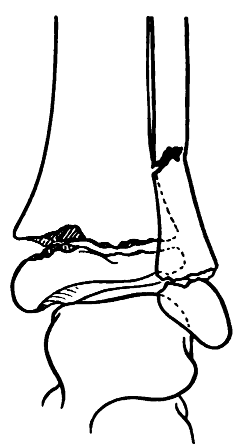


FIG. 558.—Anteroposterior view of Fi 557. Note the lateral displacement i addition to the anteroposterior shown i the first view.

pital contained 15 cases of this separation, only 5 of which involve the epiphysis alone; in the other 10 the diaphysis was also concerne (Figs. 557, 558, 559, and 560). The ages of these cases were from seve to seventeen years. Poland states that these injuries occur usuall between the ages of nine and seventeen years, that 1 out of 28 case was under nine years of age, namely, six years (Figs. 561 and 562).

The question of interference with growth is an important one as it is of all epiphyseal separations, particularly so in this regio which is so intimately concerned with the function of locomotion Coolidge[1] expresses the opinion that 1 out of 8 or 10 of these epiphysea separations result in no growth, and cites his own case as an example When six years old he fell off a fence, and the foot was found to b

[1] Boston Med. and Surg. Jour., clix, No. 15, p. 470.

loose and flabby but without open wound. The case was treated as a fracture with a good result. A year later there began to appear on the outer side of the ankle a bunch which grew steadily larger and on account of which a brace was worn for four years which made pressure on this mass, with no result except the pain it caused. The deformity increased up to sixteen years of age, when it stopped with the leg one and a half inches short, impaired in its ankle motions, and pos-

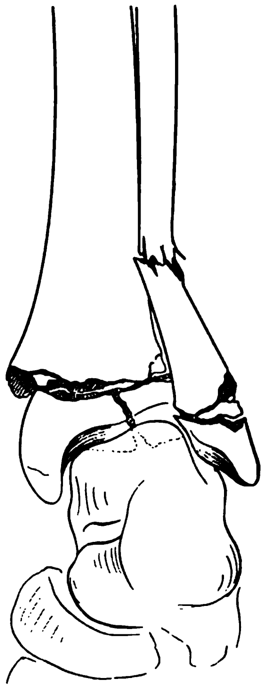


FIG. 559.—Epiphyseal separation of both bones at the lower end with a plane of separation entering the ankle-joint and a fracture of the fibula higher. One concludes that the joint complication and the fibular fracture were secondary and caused by longitudinal pressure after the epiphysis was wrenched out of place.

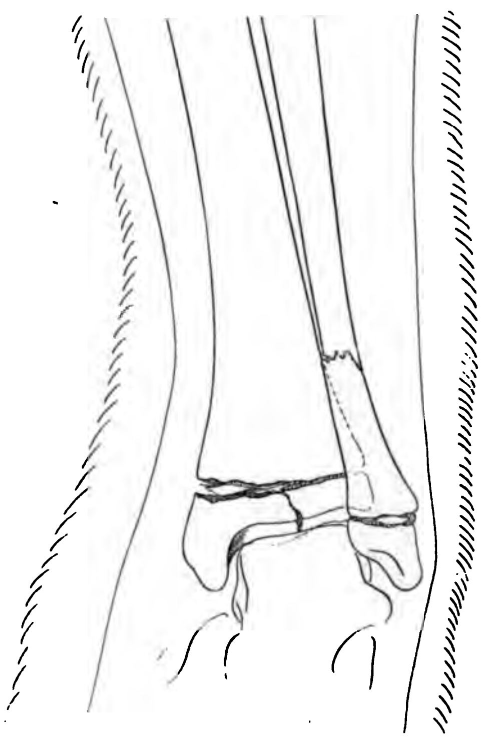


FIG. 560.—Reduction of displacement shown in Fig. 559. Note the position of adduction in which the foot is held by the plaster during repair.

sessing a tendency to roll outward. The explanation lay in the fact that the lower epiphysis of the tibia had ceased to grow after separation, but the fibula had continued to extend and has shot down below the tibia, shoving the whole foot inward so that the line of body weight extended down through the fifth metatarsal bone, and the line of the ankle mortise was very oblique. Scudder discussed Coolidge's case and gave as his opinion that interference with growth after separation

in the epiphysis is not often seen, because the epiphysis has an independent blood supply and the thick, softer periosteum is seldom all torn. For growth to be interfered with, circulation must be restricted with destruction or great displacement of the cartilage, which becomes involved in the callus. If this happens while the upper end of the bone grows more rapidly, if the injury occurs in a young child, a symmetrical growth will follow.

Diagnosis.—The diagnosis rests with the finding of a loose, displaced ankle in a child of susceptible age. The points of the malleoli bear a normal relation to each other and are not painful. There is great swelling and ecchymosis, with crepitus usually very soft or absent. If the fibula is also broken it is at a higher level, and differentiation from dislocation of the ankle hangs on the age of the patient and the normal relation between the malleoli and foot bones.

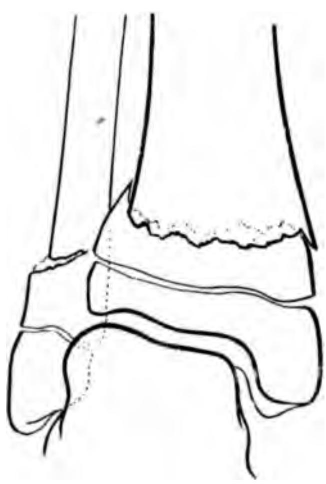


FIG. 561.—Transverse fracture just above the lower epiphysis which is clinically difficult to differentiate. The presence of distinct crepitus and the age of the patient are important points. In this patient the unclosed epiphyses did not yield.

FIG. 562.—Another type of supramalleolar fracture not involving the epiphyses. The malleoli are intact and the talus lies normally in the ankle mortise.

Treatment.—The treatment is to reduce the deformity at once. This can usually be easily done under anesthesia and the leg put in a suitable cast or splint, as suggested for supramalleolar or lower shaft fractures. Rarely reduction might fail on account of a fragment from the diaphysis. If it does, open operation with reduction must be performed at the earliest opportunity. Old cases with union in the deformed position which have never been reduced should be treated by open operation, the surgeon cutting through the callus and replacing without internal splints.

Malleolar Fractures, Internal or External Malleolus Alone or Together. Pott's Fracture. Lipping Fractures of the Posterior or Anterior Articular Surface of the Tibia.—These conditions must all be dealt with under one general heading, as the causes are common factors, the results varying with the slightest degree of difference in the amount of torsion and the bones of different individauls. Formerly all fractures involving the ankle-joint were called Pott's fractures, but the refinement of diagnosis with modern methods has changed our ideas somewhat. In another place I have recorded a study of 208 cases of ankle or Pott's fractures.[1]

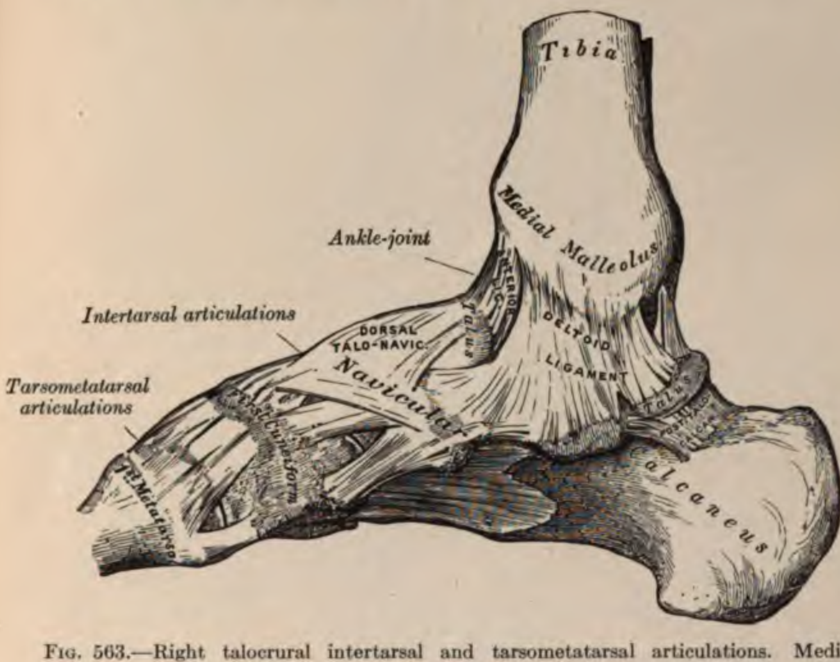


Fig. 563.—Right talocrural intertarsal and tarsometatarsal articulations. Medial aspect. (Gray.)

These ankle injuries are very common, and my investigation at the Cook County Hospital, Chicago, showed that they constituted 15 per cent. of all the fractures discharged from the institution in the year 1913. The *cause* is indirect violence and torsional strain accompanied by some compressive force from the body weight delivered through the ankle mortise. This strain is generally received on account of a twist of the foot, by a fall or slip off a small height, as a curbstone, or a fall from a height onto the foot in position of abduction or adduction. The torsion is communicated to the bones of the leg from the foot by the pressure upward, or upward and lateral of the astragalus in its mortise, aided by the pull and resistance of the ankle

[1] Speed, Surg., Gynec. and Obst., July, 1914, p. 73.

ligaments. For the sake of refreshing one's anatomical knowled conception of this important point, refer to Figs. 563 and 564, i trating the various ligaments, and Fig. 565, which portrays ex the shape and extent of the mortise which locks in the astragalu

Pathology.—When abduction and eversion of the foot are cause of the fracture, the astragalus is pushed outward, and the fi tends to break at a point above the termination of the tibiofil ligament in a transverse or oblique line from compressive force. C cidently the internal lateral ligament either ruptures or, holdin insertion into the tibia, pulls off the internal malleolus squarely its lower end (Fig. 566). If this eversion continues strongly, the l

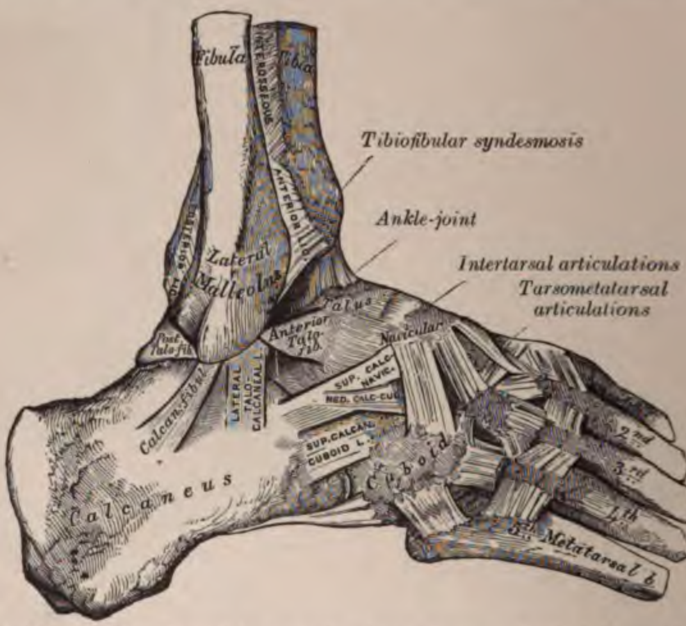


FIG. 564.—Right talocrural intertarsal and tarsometatarsal articulations. Later aspect. (Gray.)

fibular fragment may be separated a little from the tibia by tea of the tibiofibular ligament, and the internal malleolus is correspo ingly dragged outward by the internal lateral ligament, and co to lie under the joint surface (see Fig. 567). Some torsion is pres in all these cases. It is controlled and does not manifest itself pat logically because of the shape of the ankle mortise, with its str posterior lip and the very strong tibiofibular ligament. If the tors is a more predominating factor in conjunction with the eversion, obtain the spiral fractures of the external malleolus, as this pc projects lower down than the internal malleolus and meets with m of the force in external torsion and eversion. These spirals, i quickly acting force, are above the lower end of the tibiofibular li

ment which by a slight elasticity holds while the rigid bone gives, but in slower-acting force with more eversion or compressive violence from the body weight, the extreme end of the external malleolus is fractured and splintered up in a spiral manner. As a rule there is not much damage to the internal malleolus and the internal lateral ligament in this mechanism (see Fig. 568). Sometimes in eversion, in addition to fibular fracture, the tibiofibular ligament is torn, a condition permitting wide separation between the bone ends and possibly accompanied by a shell of bone pulled out from the tibia (see Figs. 569 and 570).

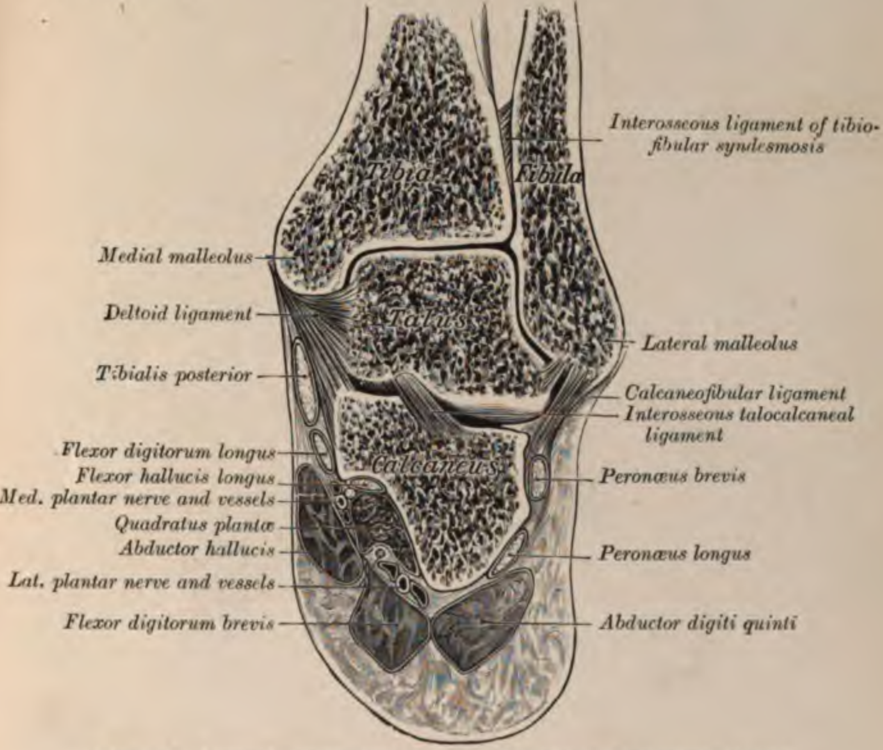


FIG. 565.—Coronal section through right talocrural and talocalcaneal joints.

True malleolar fracture must take place at a point below the insertion of the inferior tibiofibular ligament and leads to impaired motion, because the joint is opened and a small amount of callus may enter into the articular surface. A small splinter of bone may become completely detached and enter into the joint as a loose body.

If the healing process results in an angular union of the distal fragment or this callus formation, joint interference results, or chronic arthritis with painful and restricted motion ensues. For this the only remedy is open operation to remove the offending piece of bone completely, or to loosen it and reattach it at the normal angle to the

fibula. The removal gives relief from pain, and the strong latei ligament reforms, if sufficiently long rest is given the ankle.

Sprains of the ankle are a result of this mechanism when it sto short of breaking the bone. It is possible to find the lateral ligamer severely torn or even between the bones ligament ruptured and evidence of fracture present. Stimson[1] reports instances of complic tions in the nature of rotation of the fractured internal malleolus abo an anteroposterior axis, so that the broken surfaces came to lie ju

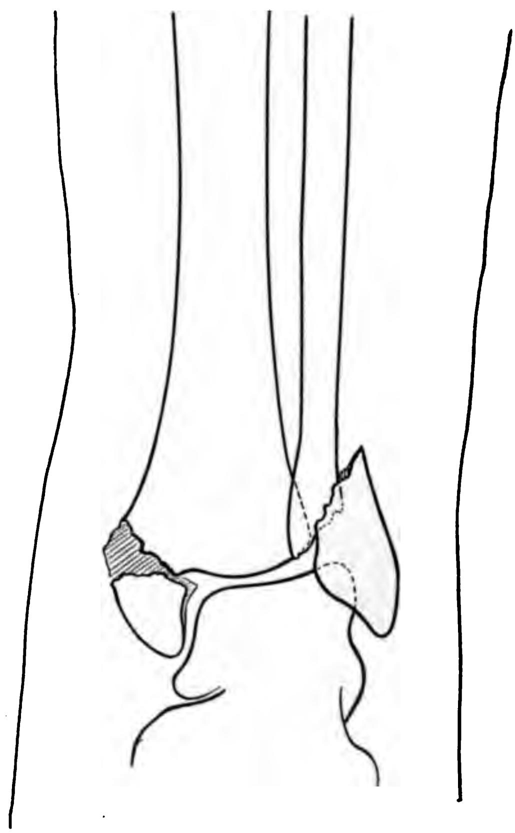


FIG. 566.—Bimalleolar fracture from abduction of the foot. Note the lateral displac ment of the talus.

beneath and parallel to the skin in a prominent manner. Anothe complication is the interposition between the tibia and the broke malleolus of a strip of periosteum. This I have observed many time in operating on these fractures. Other findings are the interpositio of tendons between the internal malleolus and tibia, holding th fractured surfaces apart. In cases of severe violence with the adde

[1] New York Med. Jour., January 26, 1889 and June 25, 1892.

compressive force of the body weight, as in falls, both malleoli are broken off, the two bones are separated at their lower ends, and the talus displaced laterally, is forced up between them. Additional lines of fracture involving the diaphysis of the tibia may be present, some of great extent (as shown in Fig. 571), and some of lesser extent, involving the anterior or posterior edge or lip of the articular surface of the tibia (Figs. 572, 573, 574, 575, and 576).

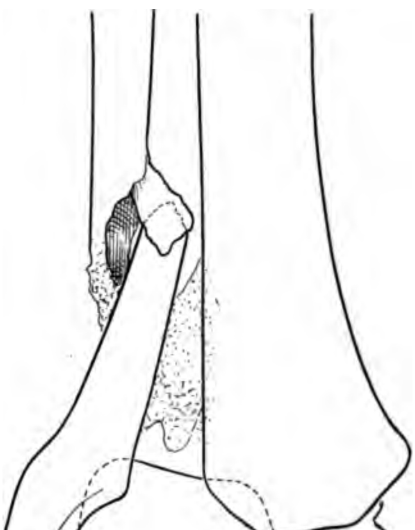


Fig. 567.—Separation of the tibio-fibular ligament, the inner malleolus being dragged under the joint. The talus is displaced upward between the two bones.

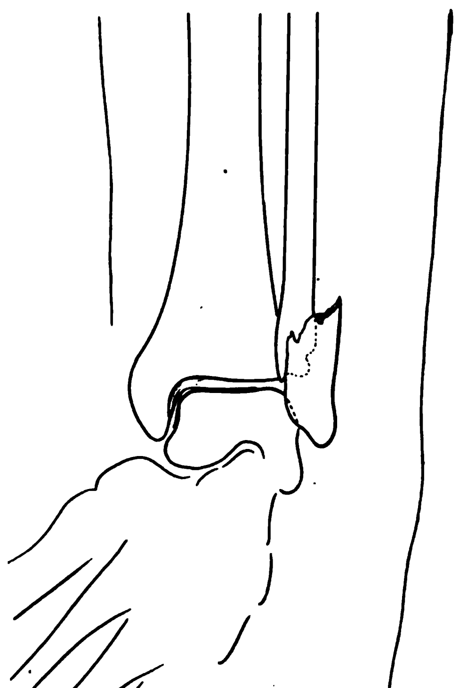


Fig. 568.—Oblique fracture of the lower end of the fibula with a plane entering ankle-joint. Note that the foot is dressed in marked inversion and yet the malleolus is not dragged down into place. This results from laceration of the external lateral ligament. The persisting displacement may be taken as an indication for nailing by open operation.

Some of these fractures are open because the skin is stretched over the inner aspect of the ankle, or because it is torn by external objects or punctured by the fragment of the tibia in a continuation of the compressive force from the body weight. Posterior or anterior displacement of the foot and talus are rare, unless the corre-

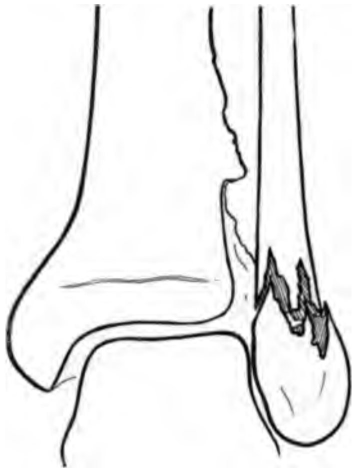


Fig. 569.—Fracture of the external malleolus with separation of the tibio-fibular ligament.

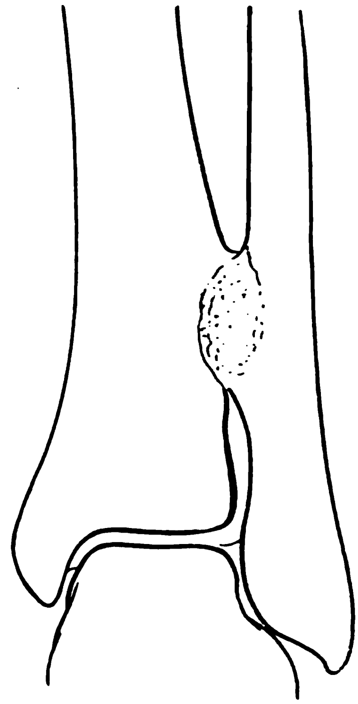


Fig. 570.—Healed separation of th ligament between the tibia and fibula The injury happened years before an there is no trace of malleolar fracture.

Fig. 571. — Fracture of both malleoli with a large fragment of the diaphysis broken off.

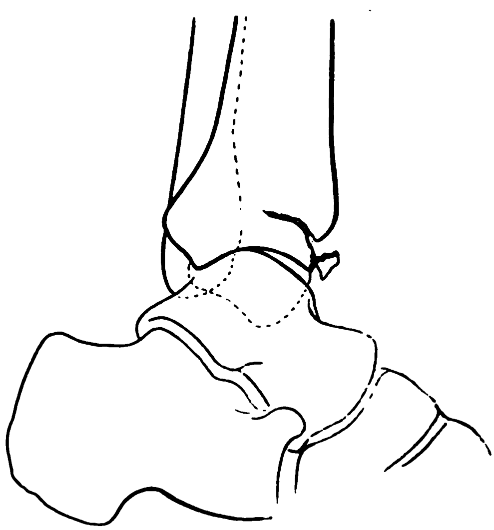


Fig. 572. — Fracture of the internal malleolus with a split-off fragment on the anterior articular surface of the tibia, lipping fracture.

sponding edges of the tibia are broken off, as is stated later in the paragraph on Lipping Fracture.

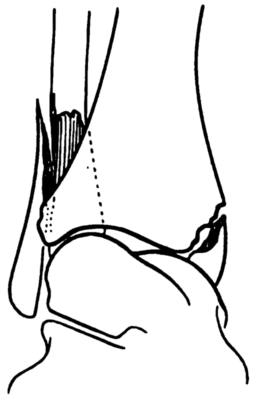


FIG. 573.—Lipping fracture of the anterior tibial border.

FIG. 574.—Unusual types of ankle fracture from longitudinal force in falls. The tibia is comminuted and there exists the so-called longitudinal fracture.

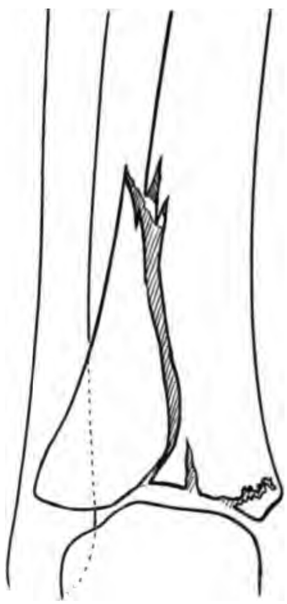


FIG. 575.—Another type of longitudinal planes of separation with some involvement of the internal malleolus.

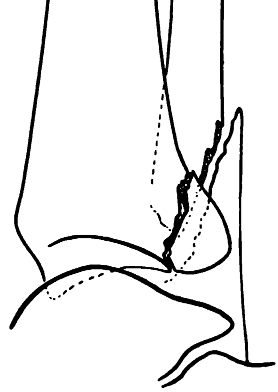


FIG. 576.—Fracture of the external malleolus and of the posterior border of the tibia.

The *definition* of the fracture named after him, given by Pott in 1764 in his book, was that of fracture of the fibula three or four inches above the external malleolus with a tearing of the internal lateral ligament. In making a study of the ankles I found the following facts:

Enumeration of Skiagraphic Studies of the Ankle Fractures.

External malleolus alone	60
External malleolus with fracture internal lateral ligament as evidenced in skiagram	31
Internal malleolus alone	10
Both malleoli	47
Appreciable separation of interosseous ligaments	10
Both bones fractured above epiphysis	12
Fracture external malleolus and epiphyseal separation	1
Lipping fracture	16
Marked displacement of astragalus:	
Inward	5
Backward	6
Outward	25
Result after setting—using tibio-astragalar axis as basis:	
Good	38
Bad	27

Analysis of these figures demonstrates that fracture of both malleoli is about two-thirds as common as fracture of the external malleolus alone, that it is five times as frequent as fracture of the internal malleolus alone, and about one and a half times as frequent as fracture of the external malleolus plus fracture of the internal lateral ligament. If external malleolar fractures alone and with internal ligament fracture are considered, they are twice as frequent as bimalleolar fracture. These figures also show that "lipping fracture" occurs in at least 10 per cent. of these ankle fractures and should be watched for in every case, and that good results, as demonstrated by the skiagrams, are not obtained in more than four-sevenths of the cases treated. Colvin,[1] of St. Paul, analyzing 60 cases of ankle fracture, reports about one-fourth as consisting of fracture of the external malleolus, one-fifteenth of internal malleolus alone, and nearly one-half as bimalleolar. He notes only 1 case out of 60 as consisting of fracture of the fibula and rupture of the internal lateral ligament, calling this the only true Pott's fracture in the series (fibula three inches above joint and rupture internal lateral ligament) (Figs. 577 and 578).

Symptoms and Signs.—*Eversion Fractures.*—In pronounced cases with separation, the swollen, useless ankle, the foot held in abduction and eversion, and the prominence of the internal malleolus or the inner edge of the tibia are sufficient to warrant a diagnosis of ankle fracture on sight. It is not so easy, however, to state on mere sight whether both malleoli are broken or whether the external alone is separated and the internal lateral ligament is torn (Figs. 579 and 580). The attendant raises the foot and leg carefully from the bed and ascer-

[1] Surg., Gynec. and Obst., 1914, xviii, 99.

tains the extent of abnormal lateral mobility at the ankle by holding the leg firmly above and flexing the foot laterally. If there is no marked

Fig. 577. — An example of the classical Pott's fracture. Note the slight lateral displacement of the talus.

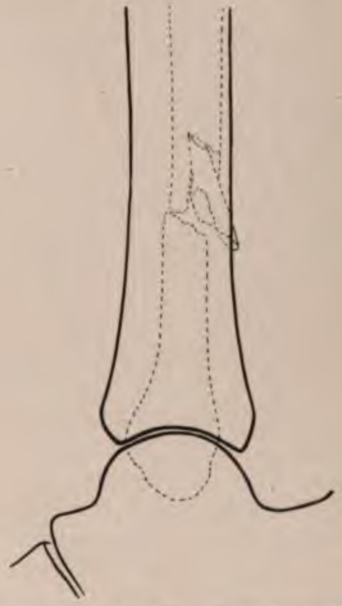


Fig. 578.—Lateral views of Pott's fracture. The damage sustained by the internal malleolus does not show. Note that the talus is not displaced backward.

Fig. 579. — Bimalleolar fracture two days old. Note the swelling around the external malleolus and the backward displacement of the foot.

Fig. 580.—Same as the preceding figure. Notice the greater amount of swelling about the internal malleolus.

motion on internal flexion, the question of separation of the interna malleolus is still an open one, but decision is usually reached quickly by a test for local points of extreme tenderness through palpation witl the tip of the index finger, or the rubber tip of a pencil. Manipulatioi for obtaining of crepitus is always painful and should not be performed as the observations of the points of tenderness are diagnostic. Occasionally the loose ends of the malleoli can be grasped between inde: finger and thumb and independent motion in them demonstrated Spiral fracture of the external malleolus is less likely to give thi: finding. If posterior displacement of the foot is noted, the complications of separation of the tibiofibular ligament, spiral fracture of the fibula, or fracture of the posterior border of the tibia must be considered (see paragraph on Lipping Fracture). With fractures low down on the external malleolus the patient can sometimes walk by having the ankle held firmly, and many of these fractures are called sprains and overlooked. Bland-Sutton[1] also believes that many of these are unrecognized and says that an articular fragment split off into the joint may unite viciously or lead to a chronic arthritis with adhesions, if it is unrecognized, and use of the ankle persisted in.

Prognosis.—A small amount of displacement permits a good prognosis with intelligent treatment. Every case should be observed by a two-way roentgenogram after it is treated, to be sure that all errors of displacement are corrected. If manipulative reduction as given under treatment is not successful in a full sense, operative recourse should be considered. In instances of bimalleolar fracture with rupture of the tibiofibular ligament and great displacement of the talus and fragments, the prognosis, even with the best treatment, is grave as to full function.

Considerable has been written lately concerning a mathematical calculation of the prognosis of ankle fractures from roentgenographic study, the lines or axes of weight-bearing force and the correct relation of joint surfaces being taken as criteria. If these are good—that is, if the joint surface of the lower tibial end and the talus bear a correct relation to each other, and a line drawn through the weight-bearing axis of the leg from the anterosuperior iliac spine straight down through the patella passes through the middle of the talus body—the prognosis for a useful weight-bearing function of the foot and ankle is excellent. It is said that one can disregard the position of fragments if these points are satisfactorily established, but I believe that stand is not well taken; for the powerful supporting lateral ligaments of the ankle, attached as they are to the lower tips of the malleoli above, must be replaced in a position of relative balance and allowed to heal in that position before useful painless function can be hoped for, and this can only be accomplished by the replacing of these malleoli in normal position and reëstablishment of the conformity of the tibio-astragaloid articulation.

[1] Lancet, February 7, 1914.

Of great importance also are the lipping fractures involving the tibia with posterior or anterior displacements of the astragalus.

An anteroposterior skiagram may not show these, or a picture taken after reduction may show a good result as far as the restoration of the mortise is concerned, which if further analyzed by a lateral view, would show a displaced lipped fragment of the tibia and give a poor prognosis for the full use of the ankle. The astragalus head rests firmly mortised between the two malleoli, which lock it in and hold the articulating surface directly under the lower joint surface of the tibia, which is the bone of weight-bearing. As Skinner has advised,[1] the anteroposterior skiagram should give us information in regard to the condition of this mortise, and the exposure should be made with the centre of the focus about an inch above the centre of a line drawn between the two malleoli, the foot being held at right angles to the leg.

The author believes that close attention should be paid consequently to the exact findings of each ankle fracture, and each case should be treated conscientiously and intelligently according to the findings. Among the laboring class nothing so interferes with wage-earning as weakened-leg support, and the whole train of life consequent upon the ability to get about on two good feet is very different from that which follows the permanent and partial disability of a bad ankle. These fractures do have some permanent impairment of function even when treated by the very best methods devised to date, and each man so afflicted should be given the best attention to shorten his disability and should not be allowed to use the ankle until callus is hard enough and ligaments are firmly enough healed to bear his weight, and not cause a further interference with his wage-earning power within a few weeks after he has returned to his occupation. The ankle fractures may mean in every case except those of the slightest crack a disability of three months, and in severe cases nine to fifteen months is not unusual.

Treatment.—If the lower end of the fibula alone has been split or twisted by the trauma, treatment should attempt to hold the astragalus well up against the internal malleolus and then to drag the cracked or broken external malleolus over to its proper position by forced inversion, with dependence on such fibers of the external lateral ligament as are still intact (Fig. 581). Dupuytren's splint of a heavily padded board applied from the knee to beyond the foot can often be employed immediately after the fracture is seen, and the foot started toward the desired position of inversion. The fault with the use of this splint has lain in the fact that not nearly enough padding has been used just above the ankle to permit the foot to be bandaged over and held in inversion. Each day the dressings can be reapplied and more inversion obtained. This does not contemplate correction of marked posterior displacement. After a week's use of this splint a circular cast

[1] Tr. Internat. Cong. Med., London, 1913; Surg., Gynec. and Obst., 1914, xviii, 238; Arch. of Roentgen-ray, 1913, p. 345.

or a moulded plaster splint should be applied, as the swelling in the ankle will have nearly disappeared. Stimson's moulded splint, consisting of one strip down the back of the leg and another laterally to hold the foot inverted, is excellent. I have modified this by using but one piece about six inches wide starting over the head of the fibula, passing down the leg under the arch of the foot and over the dorsum just to meet the external wing on the top of the foot. This should be wide enough to come over the heel and furnish some support in an anteroposterior direction, and the foot should be held in the degree of inversion desired while the plaster hardens after application of a circular bandage. This splint is readily removed for inspection or dressing in case of open operation and can be reapplied by being bandaged as firmly as in the first instance (see Figs. 582 and 583).

FIG. 581. — Treatment of fracture of the external malleolus by inversion of the foot in a plaster encasement.

Teaching of treatment by inversion for ankle fractures has been wide-spread and often misinterpreted and wrongly applied when a complete diagnosis of the lesion was not made. One case of suit for malpractice, which was based on the position in which the foot was dressed, was reported in the *Journal of the American Medical Association.*[1] In this case the suit was based mainly on the fact that the defendant (the practitioner) did not treat the foot by inversion, the assertion being advanced that he was not familiar with this proper method of treatment. A splintering of the fibula and laceration of the ligaments was the acknowledged pathology. The doctor's defense was that on account of the patient's age, fifty-two years, and of the fact that when first seen and for three weeks thereafter his ankle was very ecchymotic and swollen, he did not put it in inversion at first, because of the swelling and later because bony union was already started and no good would be accomplished. The court sustained the doctor inasmuch as it was not proved that he had been negligent in the existing case, regardless of the conduct necessary in *general* treatment of these injuries under other conditions, in which the treatment given might have been complained of as being negligent.

Should both malleoli be broken off, our method of treatment becomes a more difficult task. Here forced inversion alone is not sufficient,

[1] Jour. Am. Med. Assn., lxii, No. 18, p. 1599; Marchaud vs. Belin, Wisconsin, 147, N. W. R., 1033.

as, in bimalleolar fracture, we can always look for displacement of the astragalus either out or in, forward or back, according to the direction of the causative trauma; so the real treatment consists in returning the astragalus to the weight-bearing axis and then fixing the malleoli in some such way that they hold the astragalus in that position (Fig. 584). This can sometimes be done through manipulation and a subsequent application of plaster swathe or cast, but many cases require nailing to hold both sides in position. Where bimalleolar

Fig. 582.—The author's moulded splint for malleolar fractures.

Fig. 583.—Side view of the moulded splint for ankle fractures.

fracture is complicated by rupture of the interosseous ligament and a separation of the lower ends of the two bones, with a possible forcing upward of the talus between them, nothing short of open operation to press the two bones together, to return the talus to its proper articular position, and to nail on the two malleoli and the tibia to the fibula will preserve good function and prevent the wide painful ankle. After such operation or happy mechanical reduction in bimalleolar fracture the foot should not be put up in adduction, but should rest at a right angle and be allowed a long immobilization that the

malleoli may unite firmly with a minimum of callus, and this callus mature; also that the torn ligaments may reunite, a process which

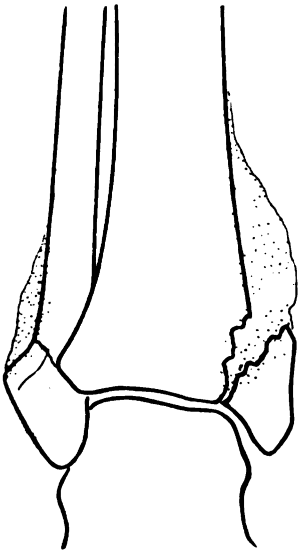


FIG. 584. — Healed bimalleolar fracture treated by a cast. The talus is in fair position under the tibia and there is ample callus cementing the malleoli. A better than average result.

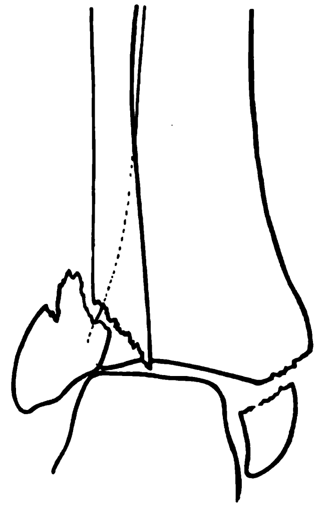


FIG. 585.—Bimalleolar fracture with outward displacement of the talus.

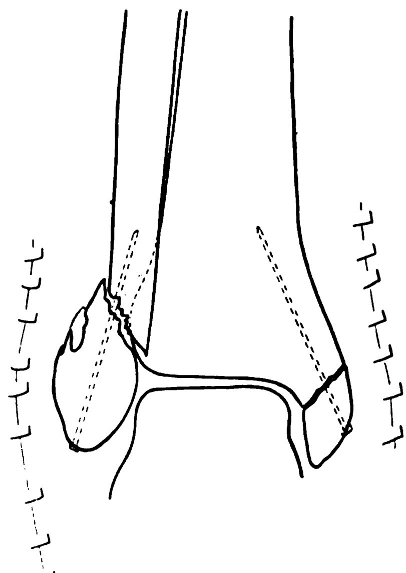


FIG. 586.—Repair of the preceding by nails. Note the skin clips in the incision and the return of each malleolus to its normal position.

takes longer than bony union, and a normal circulation of rest in the ankle may be established (Figs. 585, 586, and 587). When the splint is removed after six weeks, a very light massage and passive motion may be indulged in, but not to a point of pain at any time, and no weight-bearing on the foot should be allowed for two or three weeks. Then the weight may be gradually applied. If the attempt is painful, the fact is ample evidence that the callus is not yet matured and a further wait is necessary (Figs. 588 and 589).

At the inception of weight-bearing, if the external malleolus has been the greatest sufferer in the fracture, the patient should be cau-

Fig. 587.—The two ankles in preceding operation. Note that the bony points of the two malleoli on the injured ankle appear beneath the skin in their normal positions. Foot just out of cast, wounds long since healed. Loss of toes an old injury.

tioned to hold the foot straight forward or with toes turned slightly in and the inner side of the heel and sole should be raised slightly. This holds the foot in better weight-bearing axis and helps avoid a yielding of the young callus in the fibula and the weakened internal lateral ligament.

Malleolar Fractures Caused by Inversion of the Foot.—If the enumeration above is referred to it is found that fracture of the internal malleolus alone occurs one-ninth as frequently as that of the external malleolus, and as this injury results from inversion, which may also cause bimalleolar fracture, this position at the time of injury must

This separation of the fibula in the young may take place through the epiphyseal area, as in the wrist.

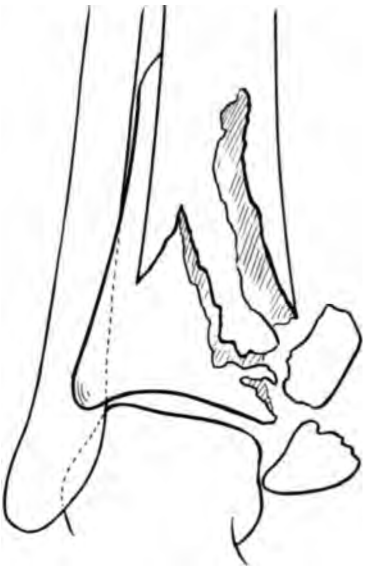


FIG. 590.—Fracture of the inner malleolus with much comminution of the tibia above. The talus is rotated outward a little, the fracture following a fall on the abducted foot.

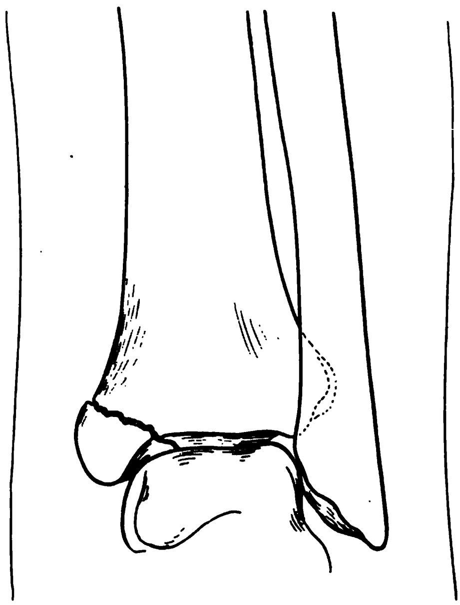


FIG. 591.—Fracture of the internal malleolus alone.

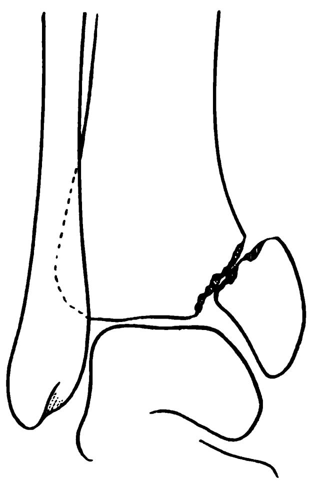


FIG. 592.—Fracture of the internal malleolus alone from adduction violence. Note the upward displacement and the opening of the ankle-joint.

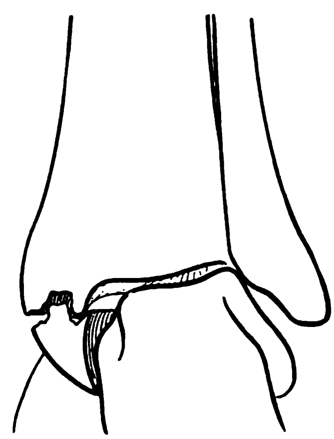


FIG. 593.—Fracture of the internal malleolus with eversion of the foot, the external malleolus being intact. This is a rare type.

The pathological findings are similar to those of external malleolar or bimalleolar fracture, and the diagnosis is made by means of the points of tenderness or the loose fragments on the tibial side. Treatment is the same as in the preceding fracture reversed, if the internal malleolus alone is broken. If the tibiofibular ligaments are ruptured, or both malleoli are split off and there is a wide ankle, the very best results are obtained by the attendant nailing each side on in its proper position and putting up the foot in a moulded splint or cast in a normal position, that is, straight as to its weight-bearing axis in relation to the talus and forward in the right position from the

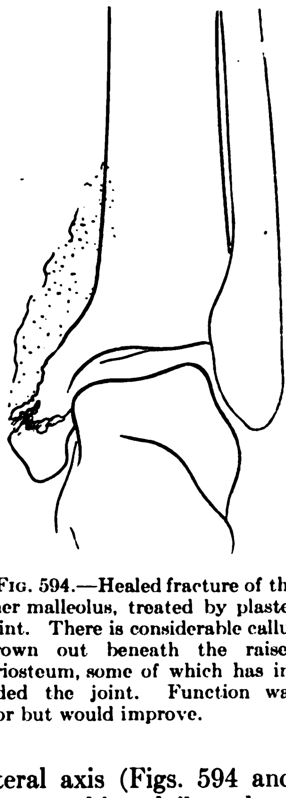


FIG. 594.—Healed fracture of the inner malleolus, treated by plaster splint. There is considerable callus thrown out beneath the raised periosteum, some of which has invaded the joint. Function was poor but would improve.

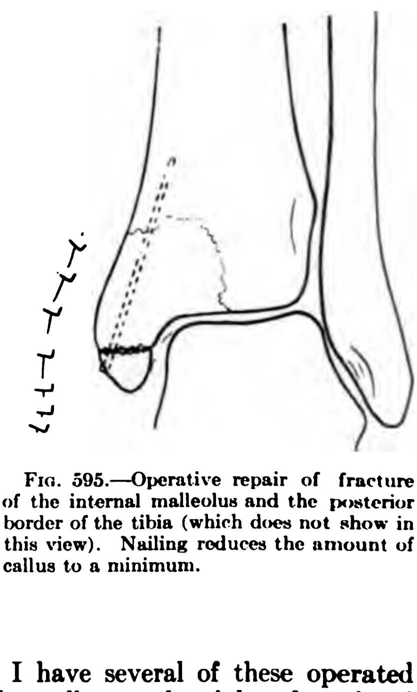


FIG. 595.—Operative repair of fracture of the internal malleolus and the posterior border of the tibia (which does not show in this view). Nailing reduces the amount of callus to a minimum.

lateral axis (Figs. 594 and 595). I have several of these operated cases working daily, who obtained excellent and painless functional results. In some the nails have been imbedded over three years and caused no trouble. Some permanent thickening of the ankle results, even with early and careful reposition, because of callus formation and thickening of the repaired ligaments coupled with circulatory changes.

Fractures of the Articular Surface of the Tibia Anterior and Posterior. Lipping Fractures.—Besides the mathematical calculation of position of the talus by a line drawn through the long axis of the tibia, one must take into consideration fracture of the extreme edge or lip of the articular surface of the tibia. By this I mean a

splitting off of a wedge-like piece, usually of the compact bone alone, the line of fracture starting at the joint and extending upward along the shaft for a varying distance of one-half to two inches or more. These are much like the sprain fracture at the wrist and are caused by a similar mechanism, *i. e.*, wedging force upward by the talus, which force may be in a direct line upward or at a varying angle and directed toward any side of the lower end of the tibia, depending on the position of the foot at the time of the trauma and the additional pulling, tearing out stress of the capsular ligament and tibiofibular posterior ligaments, with torsion on the bone surface. To these I have applied the term "lipping fractures." The importance of the posterior lip particularly has long been known and was described in the past as the third fragment in ankle fractures. Astley Cooper called it the external intermediate fragment; Tillaux, the classic fragment, etc. Older authorities as Earl Adams, Dupuytren, Malgaigne, and Hamilton considered the posterior luxation of the foot the most important point and the ligamentous rupture and malleolar and posterior fragments accessory. Destot[1] states that he has insisted on this posterior fragment for sixteen years, regardless of its primary or secondary occurrence because of its influence on treatment and prognosis. He entitles it the "third malleolus." If the tibiotarsal equilibrium is not changed, he believes that an osseous cicatrix on the joint surface causes arthritis or a spicule may interfere with tendon action or be the source of reflex trouble. When the posterior fragment is not displaced, it is negligible. Destot collected 172 cases of fracture of the posterior margin, 2 of which were isolated, 4 combined with the internal malleolus, and 24 others of the anterior margin. If these fragments are not replaced, although the talus may be situated quite perfectly anatomically and the fracture of either malleolus be but a mere split, a great interference in function results. This outcome is explained by the fact that under this misplaced shell of bone shoved down in front of the ankle-joint at some quarter of its circumference callus is thrown out which later, by its presence and possible adherence to capsular ligament or the talus, causes marked interference with full flexion or extension of the ankle-joint, and provokes much pain after use of the joint by mechanically impinging against the talus. Such ankles may show perfect alignment of malleoli and talus and yet be extremely painful after mild use. These lipping fragments should be searched for carefully, both clinically and in the skiagram, and replaced by hyperextension or hyperflexion at the time the fracture is set. If they cannot be reduced by manipulation, I believe they should be nailed on in correct position through a small skin opening, after which, if malleolar fracture is present, the foot can be put up in the proper position to meet the demands of the case. I find this condition mentioned by Robert Jones.[2]

The author's study shows that displacement of the talus, when

[1] Lyons Chir., 1913, p. 256–391.
[2] Am. Jour. Orthop. Surg., 1913, xi, 314.

its changed position is marked enough to be called a displacement is five times as frequent outward as it is inward or backward, whe all types of fractures, whether of one malleolus or both are considered Where both malleoli are broken, a putting of the foot in adductio alone would not be sufficient, even if the talus were displace outward five times as frequently as any other direction; but, a expressed before, the malleoli must be returned to normal positio and then, if it is necessary to retain the replaced dislocation of th foot, it should be put up in adduction. If the malleoli are nailed o the foot can be held in marked adduction without fear of disturbin the replaced malleoli and every opportunity given to the importa internal lateral ligament for a strong healing.

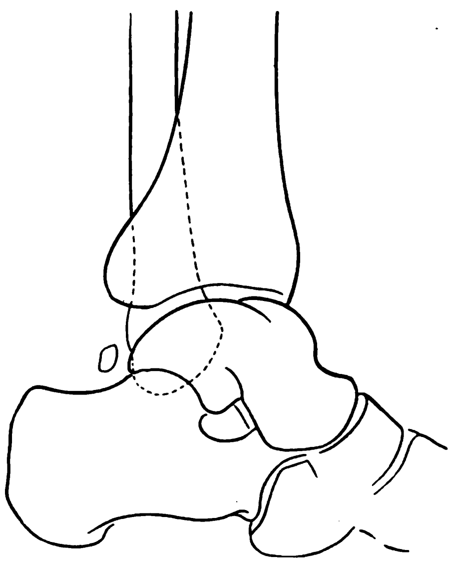


FIG. 596.—An example of os trigonum which may be mistaken for a small bone fragme after ankle injury. See Fractures of the Talus.

In 1900 Bondet[1] concluded that the posterior displacement of th foot in malleolar fractures is produced: first, by dislocation of th tibiotarsal mortise; second, by combined action of weight and mus cular contraction; third, often by the existence of a posterior tibia fragment—the presence of which is not revealed except by a skiagram (Fig. 596).

In 6000 radiographs from the clinic of the Charité at Berlin, Pels did not find a single case of pure tibiotalus luxation—*i. e.*, with without fracture—as in every case either the anterior or posterio border of the tibia or both were fractured. In 1907 Grashey,[3] i 1500 roentgenograms, found 4 of the posterior tibial margin, and a yea

[1] Lyons, 1900. [2] Berl. klin. Wchnschr., 1905, No. 5.
[3] Fortschr. a. d. Geb. d. Röntgenstrahlen.

later Meissner,[1] in Bruns's clinic, stated he had seen 19 cases: 1 with isolated fracture of the posterior tibial margin; 8 with fracture of both malleoli; 1 with fracture of the internal malleolus; 5 with fracture of the fibula; 4 with epiphyseal separation.

Later, Chaput[2] noted 42 cases in 136 skiagrams of malleolar fractures and says that from a clinical point of view the small fragments interfere with extension and are the origin of hyperostoses, while large fragments cause a posterior subluxation of the talus. Their reduction is difficult, and they often complicate ankylosis in bad position with considerable hyperostoses.

Destot,[3] in 1911, gives as signs the pointing forward of the tibia and the difficulty of reducing and maintaining the reduction. He

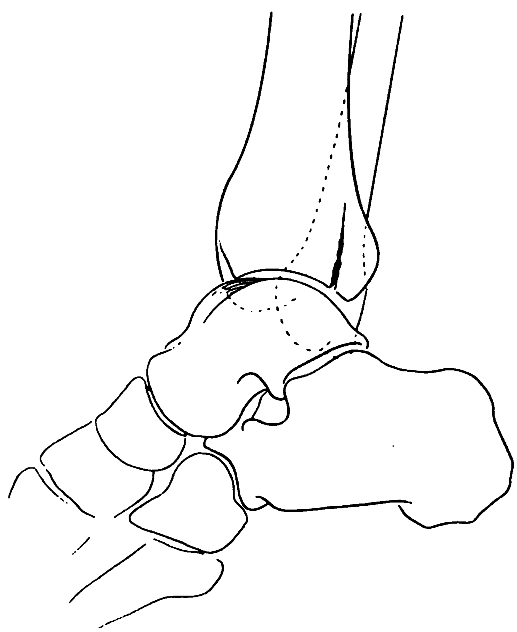


FIG. 597.—Vertical fracture of the posterior edge of the tibia.

believes that the marked enlargement of the internal malleolus and the rare possibility of feeling the tibial fragment in the retromalleolar depression are diagnostic, and suggests that they be treated by: first, osteotomy of the fibula; second, a cutting off of the posterior tibial surface by an osteotome introduced along its posterior wall; third, open operation.

In the same year Quenu[4] reported 15 cases as follows (Fig. 597): 1 of posterior margin of the tibia alone; 2 accompanied by malleolar fractures; 3 accompanied by fractures of the upper end of the tibia.

[1] Beitr. z. klin. Chir., 1908, lxi. [2] Monograph, 1899.
[3] Traumatisme du Pied et Rayons X.
[4] Fractures Marginales Posterieures, Rev. de Chir., 1912.

Stimson considers the lipping break of the tibia as complic of Pott's fracture and in 1908 had never seen a recent case—all l old. He raised the fragment in 2 cases, corrected the displacen and obtained a useful foot. In 1 he removed the articular su of the tibia and leveled off the astragalus, getting a bony union a good result. From the prognostic standpoint the lipping frac is a lesion of the greatest importance, and in old cases the advisab of recourse to operation is imperative.

Mechanism.—Almost all are caused by a slipping or a fall witl foot in hyperextension and often abducted and a tearing out of articular border of the tibia by the posterior articular and tibiofib ligament, accompanied by a crushing force upward and backw

Fig. 598.—Lipping fracture of the posterior tibial border with fracture of the ext malleolus and rupture of all the ligaments which permit an extreme backward di tion of the whole foot at the talocrural joint.

transmitted by the talus. The theory is further advanced after fracture of the fibula a continuation of the line of force now meeting resistance comes against the lip of the posterior artic surface and chips it off. This theory is very plausible, but does explain cases of isolated fracture of the posterior or anterior lip. F ture of the posterior lip alone has been considered very rare. Qu finds but 3 cases to which he adds a fourth, and Plagemann ment finding but 2 cases in eighteen years of practice.

Examination generally shows painful extension or flexion, and tho an anteroposterior roentgenogram may show no trace of fract the lateral view shows the lines in the tibia (Fig. 598). Clinica it is quite impossible to obtain a point of extreme local tender over these isolated lipping fractures or to obtain crepitation, bu

so-called Pott's fracture, with marked posterior displacement of the foot and the absence of injury or deformity in the tarsal bones, one should suspect these breaks. Without a skiagram and where the lipping fracture exists with little displacement of its fragment one may rely partly on the presence of an extended ecchymosis along the posterior surface of the ankle or a point of extreme tenderness to pressure under the calcaneus tendon in the depression back of the malleoli. The amount of displacement of the foot seems to give no key to the possibility of lipping fractures; the amount of separation of the tibiofibular joint or the laceration of this ligament may give indication, but the surest means of detection is careful study of the dried roentgenogram. Posterior displacement of the foot does not occur in ordinary Pott's, and where it does we must consider clinically that something more has happened in the ankle area than mere fracture of the fibula. If the fibula is broken three or four inches above its lower end, if the internal lateral ligament is ruptured at the same time, or if the tip of the internal malleolus is pulled off, we shall not get a posterior displacement of the foot. If all the soft parts around both malleoli are severed, if both lateral ligaments are cut, there will be no posterior displacement of the foot.

If then, we find such posterior foot displacement, what must we consider? A displacement backward of the talus can only occur when the external malleolus is freed fully from the external side of the lower end of the tibia. Should both malleoli be broken and the tibiofibular junction and ligament remain intact, no posterior displacement presents itself, although we might find all degrees of internal or external displacement. To obtain the freedom of the external malleolus, then, we must have either a fracture very low down on the external malleolus, which allows the lower fragment, with its attached strong ligaments, to slip backward, or a diastasis of the tibiofibular junction with laceration of its ligament, or possibly a fracture of the fibula high up with its line extending down into the tibiotarsal joint. There seems to be little doubt that fracture of the posterior lip of the tibia of varying degree is caused by a further action of the force of separation of the tibiofibular ligament, which, being stronger than the bony surface into which it is inserted, pulls out the corner of the tibia and preserves its own fibers intact but allows the separation and displacement of the talus. To this is added, of course, lesions of the two lateral ligaments or the malleoli. The foot, in so being displaced posteriorly, drags with it, in practically every case, its malleoli. Hence we conclude that fracture of the posterior tibial lip alone is not sufficient to allow posterior displacement of the foot, even when accompanied by malleolar damage, unless the external malleolus is freed as mentioned.

Treatment.—Treatment for all ankle fractures should be prompt reduction under anesthesia, the possible exceptions being those cases greatly traumatized and swollen beyond manipulation. If lipping fragments or sharply pointed malleolar fragments threaten to necro-

tize through the skin, they should be reduced at once. Old fractures may be reduced after three or four weeks by manipulation or by open operation, consisting of osteotomy of the fibula, operation for removal or replacement of marginal pieces, perhaps by their being nailed on, or, in severe cases, operation on the articular surface of the tibia accompanied by fibular osteotomy and a clearing out of the callus in the tibiofibular ligamentous area. Other cases may be best handled by a leveling operation on the head of the talus, with replacement in the weight-bearing axis or a complete astragalectomy.

FRACTURES OF THE FIBULA.

Fractures of this bone alone are rare except at the lower end. These were considered under the heading of Ankle Fractures.

Fracture of the upper end of the fibula alone is caused by direct violence, or by muscular contraction of the biceps femoris muscle. Adduction of the leg may result in sprain fractures and epiphyseal separations of the upper end. The line of fracture is usually transverse, or the head of the bone may be comminuted and much displaced (Fig. 599). It is drawn upward by the biceps and is difficult to restore to position. Flexion of the leg may relax the biceps enough to permit full reduction. Sprain fractures and epiphyseal separations do not result in much separation.

Diagnosis.—The diagnosis is made by the finding of the loose fragment, pain, crepitus, and interference with knee action (Fig. 600). The leg is usually held in a flexed position. Sprain fractures are diagnosed by the ecchymoses, the recurring point of tenderness to pressure, and the roentgenogram. The upper end of the bone lies without the knee-joint, and swelling or hemarthrosis does not often occur after fibular fracture. The most serious complication is injury of the external peroneal nerve as it winds around the head of the bone. It may be stretched, with temporary suspension of function and anesthesia in the leg, or it may be pressed and irritated, with resulting severe pain in the leg. Paralysis of the sural branches may come on immediately if the nerve is severed, or late if it is compressed in callus. Either condition is an indication for open operation to free the nerve or unite it when it is completely torn. Mild pressure symptoms usually disappear in ten or twelve days. I saw one case in which the peroneal paralysis was not clearly manifest until four months after the fracture. Operation was refused. It seemed that the paralysis could have been caused by the inclusion of the nerve in the callus with a very slowly proceeding pressure many weeks after bony union had taken place.

Treatment.—Treatment of fracture of the upper end of the fibula depends on the displacement. If the upper fragment is drawn upward, or the peroneal nerve is injured, open operation for reduction may be necessary. Many cases can be reduced and held by the attendant flexing the knee and applying a light moulded plaster splint. A

slight displacement or a sprain fracture can be strapped, and the patient can walk on the leg inside of a week. Little disability follows union without replacement, unless the nerve is involved.

Fractures of the shaft are caused by direct violence or by ligamentous and muscular pull in twisting of the foot. There is little displacement, because the tibia is intact and the interosseous membrane holds the fragments. The symptoms are pain in the leg after walking and a localized point of tenderness when the shaft of the fibula is examined by the fingers run down its length. There are often ecchymotic spots

FIG. 599. — Complete fracture of the upper end of the fibula without separation caused by direct violence.

FIG. 600.—Comminuted fracture of the fibula alone caused by compression and torsion.

where the violence has acted. The bone may be partly comminuted (Fig. 601). Treatment is furnished by a plaster encasement which includes the foot and wards off torsion stress on the bone in walking. Many of these fractures, especially transverse fracture with no displacement, remain undiagnosed until the continued pain and soreness after walking lead to the taking of a roentgenogram.

Epiphyseal separation at the lower end of the fibula alone is not uncommonly found in routine Roentgen-ray examination of ankle injuries (Fig. 602). It is caused by ligamentous pull on the lower

end of the bone in both inversion and eversion ankle injuries. '
is usually little separation. Treatment is supplied by an in

FIG. 601. — Oblique fracture of the lower end of the fibula above the epiphyseal line caused by direct violence. Tibia not broken and ankle mortise normal. This type is often diagnosed as sprain.

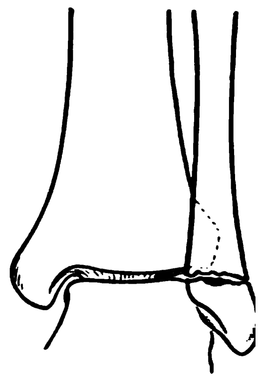


FIG. 602. — Epiphyseal sepa
of the lower end of the fibula
displacement, but persistent pa
disability.

splint of padded wood or the moulded plaster splint which hold
foot in partial adduction. Walking should be prohibited at least
weeks.

CHAPTER XXVI.

DISLOCATIONS OF THE KNEE.

For the anatomy of the ligaments of the knee-joint, the crucial ligaments, cartilages and the patella, the reader is referred to Fractures of the Tibia and Fibula and the Patella.

Dislocations of the knee are not common. I find in a compilation of 796 dislocations admitted to the Cook County Hospital, that 24 involved the knee, and a few of these were really dislocations of the semilunar cartilages. One of the knee dislocations was in a child. Classification of knee dislocations is made on the direction toward which the tibia is displaced, namely, forward, backward, outward, and inward. There are also conditions of subluxation and luxation by rotation which may combine with the other forms. Forward dislocation occurs in about half of all knee luxations, backward dislocation in one-third of all, outward, inward and rotatory luxations accounting for the remainder. Simultaneous dislocation of both knees has been reported. The character of the cause of pure knee luxations frequently leads to open wounds and to injury of the popliteal vessels. The dangers of gangrene of the extremity and infection of the large knee-joint are therefore to be considered, and many amputations after knee luxation have resulted.

Forward Dislocations.—The limit of extension of the knee is governed by the lateral and posterior joint ligaments and the anterior crucial ligament. The causes of luxation are direct violence applied to the thigh or leg, or indirect violence when the leg is held fixed. Direct violence on the leg, pushing it forward, or on the thigh above the knee, pushing it backward, are the common causes. The patient may get his leg caught in a wheel or a belt and have it twisted forward, or fall in a hole, and have the body momentum carry the femur backward into dislocation. Several cases have been reported from hyperextension of the knee in elevator accidents. Passengers in a falling cage sustain a sudden severe hyperextension of the knee when the cage strikes the bottom. Stimson reported 1 such case,[1] and Eames[2] 5 cases in a group of 18 men who were in a car which dropped sixty yards down a mine shaft. The case shown in Fig. 603 occurred in a teamster who was knocked off a high seat by a collision with a street car. He sustained also a skull fracture.

Pathology.—The luxation may be complete or incomplete, more often the latter. Open dislocations also frequently result from severe

[1] Fractures and Dislocations, 7th ed., p. 851.
[2] British Med. Jour., 1900, i, 908.

direct violence in power belt and wheel accidents, the wound caused by the trauma or resulting from the overstretching soft parts on the condyles of the femur behind the joint. Incon

FIG. 603.—Uncomplicated complete anterior dislocation of the knee. Note the for traction applied over the padded ankle.

anterior luxation need not rupture the capsular ligament at far as any clinical evidence shows. Autopsy findings confirm fact. I have seen one incomplete anterior luxation in a large which did not cause even a demonstrable amount of fluid in the

FIG. 604.—Lateral view of a complete anterior dislocation of the knee shown 603. Note the skin line showing the bulging forward of the knee and the angula tion of the patella.

joint, although it was out of place over twenty-four hours. The sule of the joint could not have been ruptured, because there we hemarthrosis and no skin ecchymoses. Between the articular su

of the tibia and the femoral condyles in incomplete luxation there is still an area of contact, and the anterior crucial ligament alone may be ruptured. Complete anterior luxation necessitates the displacement of tibial surface above the lower end of the femur—usually a distance of one or two inches (Fig. 604). The lateral and posterior ligaments of the joint, both crucial ligaments, and possibly the hamstring tendons are torn. Rarely the calf muscles are lacerated and the popliteal nerves are ruptured. In open dislocation we may expect injury of the popliteal artery and vein; their rupture has been recorded in closed luxations. When the femur appears through the skin opening it may show evidence of the pulling out of the posterior ligament from its surface, small pieces of bone being avulsed. The ligament may rupture at other points and permit the femur to escape through the rent.

Injuries of the popliteal vessels vary. The inner coats may be ruptured with damage of the adventitia, and after reduction an aneurism develops. If the vessel is stiffened it may rupture in part, especially in calcified areas of the wall, or a thrombus may form in the vein after reduction. Occasionally the vessels are so compressed that circulation through them ceases during the continuance of the luxation, but is renewed without untoward effect when reduction eases them off. If the knee-joint becomes infected in open luxation, pyarthrosis with a stiffened joint or a subsequent amputation may be the outcome. The amputated legs have given excellent opportunities for the examination of the pathological lesions.

Fracture of the spines of the tibia and dislocation of the semilunar cartilages may accompany the luxation (see Fractures of the Tibial Spine). Müller[1] reported a forward luxation in a woman aged twenty-five years, who fell off a bicycle and struck her knee on the pedal. The medial spine of the tibia was broken off and the anterior crucial ligament was ruptured, but the semilunar cartilages and the capsule were uninjured. A hemarthrosis was present. Arthrotomy was done at once to remove the bone fragment and a good result followed in six months. Götjes[2] reported 23 cases of rupture of the crucial ligament which were found in the literature; 7 of these were in Tillman's clinic.

Symptoms.—In complete forward luxation the leg is extended and lies on a higher level than the thigh. The prolonged longitudinal axis of the leg strikes above the femur. Behind can be felt the bulging condyles of the femur, and in front the upper articular surface of the tibia, with the patella riding against it tipped at any angle up to 90 degrees. Posteriorly the skin and hamstring tendons are tense. anteriorly the skin lies in a deep fold behind the upper tibial surface. Swelling and hemarthrosis are usually prompt complications in complete luxation. The joint may be quite freely movable if all the liga-

[1] Beitr. z. klin. Chir., 1914, xciv, 221.
[2] Deutsch. Ztschr. f. Chir., 1913, Bd. cxxiii.

ments are torn; if they remain intact it is fixed, and attempts to the leg are painful and resisted. Lateral movements and even hy extension may be present. Incomplete luxation gives less pronoun findings, which may be marked by swelling and joint distention. roentgenogram will decide the positions of the tibia and femur, o subluxation is suspected, the leg may be given treatment looking tow reduction before it is put to rest and the swelling reduced. O dislocation usually has a posterior wound, transversely across femoral condyles, which protrude or are seen in the opened joint. Ne and vessel injury are difficult to diagnose unless the vessel is torn an open wound and hemorrhage ensues. Tingling and numbness the foot indicate nerve pressure, lack of sensation, nerve avulsi The dorsalis pedis artery is the best guide for an intact arterial tru Nerve and vessel injuries may have delayed symptoms, and beginn gangrene may not be evidenced until several days after reducti Paralysis of muscle groups may also be uncertain for some time af luxation and may be accompanied by atrophy and trophic ulcerati on the ankle and foot.

Treatment.—Reduction can sometimes be performed without a anesthesia by simple traction in the long axis of the leg, the th being counter-extended. A broad bandage around the padded an gives sufficient hold to make traction by its loose ends, the jo readily sliding back into place. If this simple method of reduct fails, the leg can be hyperextended and drawn downward while dir pressure is made backward on the head of the tibia. Risk of additio injury of the vessels and nerves is caused by this procedure, and I ha never found it necessary. A posterior padded splint or a plaster enca ment from hip to toes will hold the reduction, the leg being sligh flexed. After a gentle reduction no increased swelling of the kn joint need be anticipated, but if a circular plaster encasement is u it should be cut out over the anterior part of the knee that the att dant may observe the condition of pressure. Immobilization is nec sary for four to six weeks to give the crucial and joint ligaments opportunity to heal. Weight-bearing on the leg is deferred until t joint feels secure and is not at all painful. When walking is attempt too soon the healing ligaments stretch, the joint becomes uncerta and some disability is permanent. An elastic knee-cap should worn for six months to a year and every precaution must be tak to avoid exaggerated motions of the joint. A slight partial restricti of knee-joint action is a common result in uncomplicated cases.

In cases of vessel injury with gangrene started it is better to perfo early amputation above the knee than to wait for a line of demar tion and toxic absorption which lessens the chance of recovery. Op luxation has a grave prognosis both as to life and loss of the leg.

Backward Dislocations.—Backward knee luxation is less comm than forward. Velpeau made the first study of the condition and la Malgaigne gathered 80 cases of knee dislocation, only 12 of wh were backward. Isolated cases have appeared in the literature sin

A recent study was made by Hardoüin[1] (Fig. 605). He finds only 17 cases in the French literature since Malgaigne. Direct posterior dislocation may be complete or incomplete. The luxation may also be back and outward or inward, and like anterior displacement, accompanied by rotation.

The causes are direct and indirect violence, the former acting on the tibia or femur and the latter acting by the force of body weight driving the thigh forward while the leg is held fixed. Wheel accidents, especially in younger persons, cause dislocation by the catching of the leg between the spokes and body of the vehicle, the knee being forced into luxation by the leverage of direct violence. Shafting and machinery-belt injuries account for many luxations of adults.

Pathology.—Hardoüin states that there are 27 cases of posterior dislocation in which autopsy or open operation have given definite information of the pathology; 13 of these were direct dislocation backward. The head of the tibia slides backward, directed outward and inward, or inward by the intact and holding ligaments. Incomplete posterior luxation is possible with an intact anterior ligament. Complete dislocation is impossible unless the posterior crucial ligament is ruptured, but the anterior crucial and joint ligament may be stretched and elongated. All clinically known forms of knee dislocation have been produced experimentally on the cadaver, and the findings indicate that there is preservation of much of the ligamentous structure, especially of the lateral ligaments. A concomitant luxation of the fibula on the tibia has been found in some cases. If all ligaments are destroyed, the head of the tibia can be carried in any direction, the joint being very loose. The usual type, however, preserves a considerable part of the joint surroundings. In a case in which amputation was performed by Bernard there was a fracture of the internal tuberosity of the tibia, the lateral ligaments were intact, the posterior capsular and crucial ligaments were torn, and the popliteal vessels were obliterated. The popliteal vessels may be torn completely or in their inner coats alone, and the tubercle of the tibia may be avulsed by traction of the patellar tendon (Fig. 606). The patella may also be fractured, and open wound into the joint from direct violence has been reported.

FIG. 605.—Outline of Hardoüin's case of backward dislocation of the knee. Note the prominence of the lower end of the femur.

Other complications consist in fracture of the femur or tibia, rupture of the quadriceps muscle, and gangrene.

[1] Rev. de Chir., xlviii, 847.

Symptoms.—The knee is thickened in its anteroposterior diameter, and in complete dislocation the leg is shortened and lies in full extension. Axial lines through the femur and tibia fail to meet, and the leg may be deflected to one or the other side according to which ligaments remain intact. Palpation discovers the rounded surfaces of the femoral condyles in front of the joint with the tense skin over them and a depression below them in place of the tibia. Displacement of the patella may carry it to one side or the other, or it may lie pressed flatly into the intercondyloid notch. On the posterior surface the sharp edge of the displaced tibia is prominent, the overlapping of

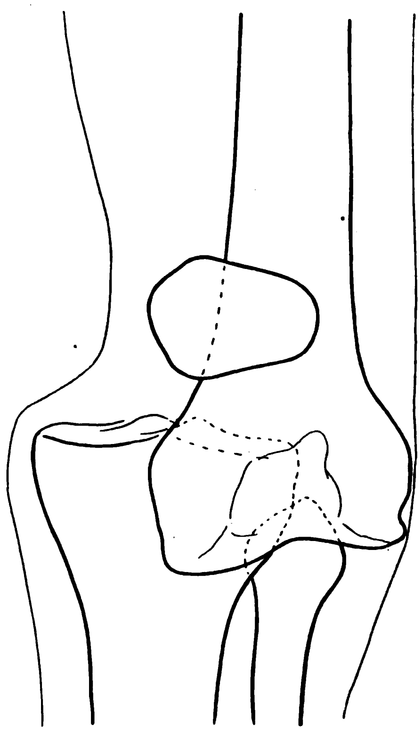


Fig. 606.—Anteroposterior view of complete anterior dislocation at the knee. Looked at from behind.

the femur varying from one to three inches. Incomplete dislocation with the head of the tibia in partial contact with the femoral condyles gives less pronounced findings. When all ligaments are torn, especially both crucial ligaments, the joint is easily moved and is unstable. Retention of part of the ligaments causes a rigid joint, with passive motion possible away from the side of damaged ligaments.

In a few instances the dislocation has never been reduced and a fairly useful false joint has developed between the bones of the knee. Karenski[1] reported a case in a thirty-two-year-old woman. The

[1] Arch. f. Chir., 1886, xxxiii, 525.

dislocation had been present sixteen years, and the function was very good. The diagnosis of accompanying fracture is often difficult, and roentgenogram in two directions should be employed.

Treatment.—Treatment in recent luxations consists in reduction by flexion and traction forward on the leg (Fig. 607). Hardoüin found that reduction was easy but that a subluxation occurred as soon as the traction was released. If this tendency is present, the leg should be placed in Buck's extension with a twenty pound weight applied for three or four weeks. The ligaments heal, and slight active motions are permitted, so that in six to eight weeks the patient can safely begin walking (Fig. 608). Mauclaire's case was one of rupture of both crucial ligaments, and they were sutured by open operation in spite of the large hemarthrosis present. A cast was applied and after its removal in forty days some subluxation backward of the knee was still present. There was also a fibrous ankylosis.

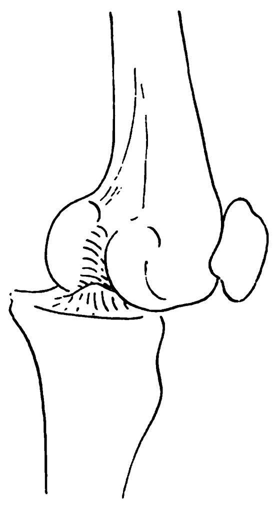


FIG. 607.—Subluxation backward of the knee without rotation.

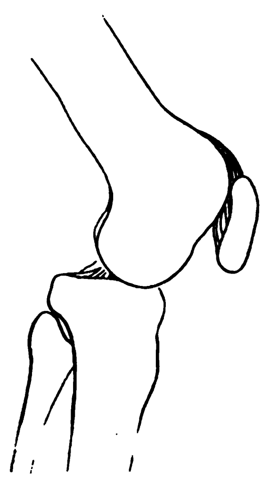


FIG. 608.—Outline of Mauclaire's case of subluxation backward.

Irreducible posterior and old dislocations are treated by arthrotomy. A long semilunar incision (Hahn's) over the front of the joint permits access to the interior. Displaced cartilages, bone spicules, and torn ligaments may be removed and the joint brought into position. The operator should use every precaution to avoid wounding or abrading the joint surfaces. Old dislocations may be reduced by simple arthrotomy combined with tenotomy of the hamstrings, or a complete arthroplasty. Formation of a new joint surface modelled out of the head of the tibia covered by an interposing flap of soft parts may be the best procedure. The extent of the operative interference depends on the age of the luxation and on the deformity.

Lateral Dislocations.—Inward dislocations are extremely rare. They are caused by excessive violence and may be accompanied by fracture of the tibia or femur, and are therefore considered from the standpoint of fracture. Complete inward dislocation involves tearing of the internal lateral ligament and possible injury of the hamstring tendons and popliteal vessels. Reduction is made without difficulty by traction on the leg and direct pressure. One case of subluxation and fracture of the tibial tuberosity which was under my care was easily reduced by my applying traction on the Hawley table and direct pressure over the deformity on the inner side of the knee, replacement occurring with a muffled snap. After-treatment consists in immobilization for four to six weeks in a moulded splint, the leg being placed in a very slight degree of flexion. Walking must be cautiously begun, and the knee should be supported by an elastic bandage, or an outside leg iron, so that abduction movements of the foot will not cause recurrence or lacerate the weak ligament.

Outward Dislocations.—Outward incomplete luxation, usually with some rotation occurs more often than inward. Complete outward dislocation is rare. The causes are twists of the leg or falls on the leg in abduction. The pressure of a heavy weight against the thigh when the leg is fixed has also caused this lateral displacement. Fowler[1] reported a case in a forty-year-old man who was pulled from a wagon a distance of three and a half feet. The leg was in flexion and somewhat abducted, the inner tuberosity of the tibia was in contact with the external condyle of the femur, and there was present a slight amount of external rotation of the leg. Active motion was absent, and the roentgenogram confirmed the diagnosis, showing a fracture of the external tuberosity of the tibia. Reduction was accomplished by direct traction and pressure over the head of the tibia. An exitus followed in eleven days from lobar pneumonia, and examination of the knee was made. The joint was distended by a bloody fluid, the outer half of the head of the tibia was comminuted, and the external lateral and anterior ligaments were torn across. The internal lateral ligament was but partly ruptured, and the posterior ligament, popliteal vessels and nerves were intact.

The vastus internus may be ruptured, as also the crucial ligament Hardoüin's experiments demonstrated that outward dislocation is impossible without rupture of the anterior crucial ligament. The patella may be displaced laterally and resist attempts at reduction. Injury of the popliteal vessels has been recorded.

Symptoms.—The knee may be abducted or adducted, and is generally partly flexed. In Duguet's case[2] the leg was flexed to an angle of 60 degrees. There is pain and loss of function, so that active movements are not possible. A bayonet deformity exists at the knee, the internal condyle of the femur appearing on the inner aspect of the joint covered by a crease in the skin, and the displaced tibial head projects on the

[1] Jour. Am. Med. Assn., 1911, lvii, 2124.
[2] Bull. et mém. Soc. de Paris, 1914, xl, 36.

outer side. Presence of the patella over the outer aspect of the joint may mask the sharp contour of the tibia. Some external rotation of the leg is also present; in wide lateral displacement there is more rotation and backward position of the external tuberosity of the tibia. The long axis of the femur and tibia do not correspond; that of the tibia lies outside.

Treatment.—Reduction is simple, by traction on the leg and pressure inward over the tibia. If there is difficulty in reduction, mechanical extension and sufficient force to unlock the two bones must be used. After reduction a Buck's extension can be employed for two weeks with fifteen to twenty pounds weight, and a plaster dressing is then worn for a couple of months to permit firm cicatrization of the lacerated ligaments before use is attempted. Duguet found that after reduction of the knee luxation the patella remained dislocated laterally, probably being held by violent contractions of the vastus internus and the loss of support of the lacerated internal ligaments. Rest and strapping eventually cured the condition. If the patella remains out of place persistently, the surgeon should not hesitate to perform an open operation to replace it and suture the ruptured capsule. Old outward luxations are treated as described in the paragraph on other old luxations, each operation being adapted to fit the findings of the individual case.

The prognosis of outward dislocation is variable. Unreduced cases may give some function. Popoff[1] collected the results in 24 cases. There were 10 favorable results, 7 unknown, 5 bad results, and 2 deaths. In Vautrin's 7 cases reported in the same year there were 2 absolute cures.

Rotatory Dislocations.—Some rotation of the leg bones is frequent in anterior and posterior luxations, as previously mentioned, because the laceration of ligaments which supported one side of the joint permits the causative force or gravity to rotate the leg. Pure rotatory dislocation implies that the leg is not displaced either forward or backward on the femur, but turns upon an axis corresponding to the longitudinal axis of the leg. The rotation may therefore be of two different characters. First the tibia rotates on a long axis passing through the spines or the centre of the upper articular surface, each side of the surface turning away from the femur in opposite directions. One tuberosity moves forward, the other backward, the centre of the tibia retaining its normal axial relation to the femur. This luxation is the complete rotatory form. A very few cases have ever been reported. In these there was laceration of the lateral ligaments, and probably of the crucial ligaments, and the muscles about the joint also suffered tearing. In one case the internal tuberosity of the tibia came to lie directly forward, while the external tuberosity lay backward in the intercondylar notch. The semilunar cartilages may be loosened by this twisting, the insertions into the fibers of the internal lateral ligament pulling out the internal cartilage. Fracture of the

[1] Thèse de Lyon, 1904.

tibial spine would also be expected. The biceps insertion may torn from the fibula, or the other hamstring tendons may be wrapp around the condyles and prevent extension of the leg.

The second type is incomplete rotatory luxation which is possil when the axial line on which the leg turns does not pass through t centre of the upper articular surface but does pass through one or t other tuberosity. This tuberosity remains in contact with the femu and the other is turned away from its respective condyle, lying final either in front of or behind it. These incomplete rotations are foun frequently in fractures through the tibial tuberosity and may al complicate anterior and posterior luxations of the knee.

Reduction in all reported cases has been easily accomplishe Traction, or flexion and traction, combined with direct pressure ov the upper end of the tibia has been the satisfactory means of trea ment. If there is a tendency for the leg to fall backward or into ar abnormal position, it should be held in straight extension by mechai ical means and a plaster encasement applied. The joint must be give prolonged rest that the ligaments may obtain strength for weigh bearing. Some partial disability follows all cases, and the patien must be cautioned against early and free use before the proper tim for weight-bearing. If this injunction is not followed, the ligament all become flabby, the joint becomes loose and tires easily. Disloca tions of other types may follow and the patient has a permanen partial disability.

So-called subluxations of the knee follow traumatic sprains whicl involve nearly always the important internal lateral ligament. Ath letes, children, and workers exposed to the conditions which result ii abduction knee sprains suffer a weakening of the internal latera ligament, which may be acute with the rupture of some of the fibers or chronic with a gradual stretching. The leg is easily abducted anc the joint seems unstable in lateral motion, so that a partial latera luxation appears clinically. The fascia and fibers of the vastus internus on the inner side of the patella may be lacerated. Reinforcement of the tendons surrounding the knee-joint is lost, and the strain falls on the capsule and crucial ligaments. These traumatic injuries shoulc not be overlooked by any surgeon because they lead to permanent weakness of the joint when they are not corrected and permitted tc heal firmly. Football players, children, and others should have the joint firmly fixed in an adhesive strapping on the inside of the knee and leg, or if the tearing is extensive enough to cause an ecchymosis the leg should be immobilized three weeks in a plaster encasement. Some of these neglected sprains lead to an ultimate loosening of the internal semilunar cartilage by the attrition which develops in the loosened joint and the traction of the attached fibers of interna lateral ligament during the unusual loose excursion of the joint outward. Evans[1] reported 2 cases of knee subluxation. The associated lesion in his case was a detachment of the anterior end of the internal semilunar cartilage.

[1] Lancet, London, 1911, i, 224.

DISLOCATION OF THE SEMILUNAR CARTILAGES.

The reader is referred to the description of the ligaments of the knee-joint in the chapter on Fracture of the Tibia. The two semilunar cartilages, wedge- and crescent-shaped, with the thick edge lying outward, each assist the opposite lateral ligament in limiting lateral movements of the leg. They are composed of fibrous tissue covered with hyaline cartilage and are often connected by a transverse ligament. On the outer border of the cartilages the capsule fibers merge into the fibers of the semilunars, forming the coronary ligaments. An additional function is possessed by the cartilages because of their movement with the tibia in flexion and extension, namely, they perform the function of a pad or shock absorber between the tibia and femur. Rotatory movements at the knee-joint, however, take place between the tibia and the cartilaginous disks, the latter remaining with the femur. This normal range of motion within the joint is very slight. A close attachment between the internal lateral ligament and the internal cartilage has been described by Griffiths,[1] who cut the internal ligament, and was able to obtain separation between the two bones at the knee when the leg was in extension. In a flexed position this separation was checked by the crucial ligaments. Consequently the greatest strain on the internal lateral ligament occurs when the foot is abducted, the knee is partly flexed, and the femur is rotated inward. These facts fully explain the mechanism of cartilage dislocation. Strain on the internal lateral ligament and the internal cartilage result when the leg is extended, when the foot is in abduction, and when the inertia of body weight as in a person getting off street cars or stepping off a height, gives an inward twist to the femur. Rupture of the internal lateral ligament, as in the cases of subluxation of the knee previously mentioned, does not affect the cartilage, if the tear takes place above the joint level. When the ligamentous tear is below the joint level, more rotation of the leg is permitted, and the cartilage follows the femur and is displaced from the tibia. Complete rupture of the coronary ligament fibers between the cartilage and ligament will permit the disc to be displaced inward toward the joint. If the twisting and abducting force separates the bones sufficiently, the cartilage slips inward, and as the bones spring back into place at the cessation of the trauma, the cartilage is caught and nipped so that the knee is painfully fixed. The force may tear or fracture the cartilage. Joint effusion follows, from irritation of the synovial membrane.

Displaced or torn cartilage may be thickened, curled up, or thinned. Fibrous nodules develop in the injured disc, and loose bodies of cartilage, fat, or organized blood-clot may also be present in the joint. As a rule the cartilage is displaced inward and acts as a mechanical wedge to fix the joint. In relatively few cases the cartilage is displaced out-

[1] British Med. Jour., 1900, ii, 1171.

ward by joint effusion or by the original trauma, and it may be pa pable on the articular margin. Jones[1] found in a series of over 4(cases that the external cartilage was dislocated in 7 per cent. Th fact is explained by the firmer fixation of the external cartilage by tl joint ligament, and the normal line of force between femur and tib which is extended through the inner side of the knee. The mo intimate connection of the internal lateral ligament with the ancho ing of the internal cartilage, and the more frequent abducted positi of the foot which produces the strains following upon outward rotati also have bearing on the less frequent displacement of the extern cartilage.

After a primary luxation the condition tends to become habitu and recurs in unguarded movements when the leg is turned suddenl Slight turns when the knee is flexed, as in the act of going downstai may be sufficient to cause many recurrences, and the patient fin use of the joint correspondingly restricted.

Symptoms.—In a primary injury the twisting strain is general a powerful one, occurring commonly in athletes. There is a sudd sickening pain in the knee, which becomes fixed in a flexed positi and cannot be extended. According to Jones, actual locking of tl joint is present in only one-half of the cases. By holding the leg flexion the patient may be able to walk on his toes to a place of assi tance. Local tenderness to pressure exists on the inner aspect of tl joint, and a palpable separation between the tibia and femur ma be felt by the surgeon when the leg is extended to the limit of tl locked position. A prompt reduction may lead to little joint effusio When the cartilage remains displaced a synovitis ensues. The joint painful for several days, even if reduction is performed immediatel and there is tenderness to pressure on the internal ligament. Earl use of the irritated joint before the cartilage has healed in positio is practically always followed by repeated attacks of dislocation a intervals of days or months. Repeated effusions further weaken th capsular structure, the cartilage undergoes retrogressive changes, an the luxation becomes an habitual one. Each time the disc remain out of position until it is reduced by manipulation, either by the patien himself or the surgeon. Constant irritation of disc luxation may lea to tuberculous joint or to serious osteo-arthritic changes.[2]

Diagnosis.—Differential diagnosis includes joint mice, or foreig bodies of any origin, which interfere with perfect freedom of motion Joint lipomata, synovial fringes, and hypertrophied villi cause con fusion in diagnosis. The history of acute locking followed by pain an joint effusion, with subsequent similar attacks, is clinically all that i needed for diagnosis. Mistakes have been made by the most eminen surgeons, but a mechanical derangement of the knee-joint whicl indicates operation is nearly always an affair of the cartilages; whe it is not, the necessary operation exposes different pathology, but th

[1] Ann. of Surg., December, 1909.
[2] Jones, Loc. cit.; Lane, Clin. Jour., London, 1900, xvi, 103.

lesion is corrected. Roentgenogram is a very unsatisfactory aid, as the disc rarely throws a distinct shadow. The picture may aid in differentiation, however, by exposing other lesions of foreign bodies and fracture of tibial spines and other portions of the bones.

Treatment.—Displacement of the cartilage must be reduced, as traumatic displacement of any luxated portion of bony framework must be, before function can be completely restored. Intimate relationship between the internal lateral ligament and the disc, a tendency to recurrence from slight causes, and the great importance of the integrity of the internal lateral ligament to the normal knee-joint, establish the following rules for treatment:

1. The primary reduction must be complete.
2. The cartilage must be given absolute rest until its attachments have united.
3. The internal lateral ligament must be guarded against strains of any kind until full strength is restored.
4. The additional injunction is made against arthrotomy for primary dislocation—unless reduction is impossible by manipulation and the knee is in a locked or functionless position.

Reduction.—No anesthesia is necessary in most cases. The patient is placed on a couch. Any method of manipulation which secures full extension of the leg is satisfactory, because that position means that the cartilage has been completely reduced. A customary procedure is first flexion of the knee with the surgeon's wrist in the popliteal space. When maximum flexion is obtained, the leg is rotated away from the injured side, that is, outward when the internal cartilage is displaced, and then quickly and fully extended. If there is any obstacle to full *voluntary* extension of the leg, the reduction is not perfect. Several attempts may be necessary before the patient can extend the leg or the knee-joint feels normal. A small proportion of cases will be irreducible—these are transferred into the habitual class at once, or are subjected to operation for removal of the disc. Refusal of operation demands palliative treatment. A longitudinal pad may be worn strapped around the knee, making pressure on the inner side of the joint, or an outside iron with a joint at the knee which inhibits rotation of the foot beyond a narrow angle may be worn. Elastic knee-caps and a raising of the inner side of the sole and heel of the shoe are also helpful. The patient leads a life of guarded use of the joint, and his activities are correspondingly restricted. Recurrence follows recurrence until the patient learns to make reductions himself. After the cartilage slips out, he sits on the ground and uses his well knee as a fulcrum in the popliteal space of the injured joint, rocking and alternately flexing and extending the leg in as much outward rotation as possible until reduction occurs.

Adherence to the rules outlined for treatment will guard against recurrence. After reduction the cartilage must be securely held in its fixed position. This fixation can be maintained only when the leg is completely extended, all rotatory and lateral movements of the

joint being interdicted. Rest in bed with the leg on a posterior padde splint is insisted upon until the joint effusion subsides, and then plaster encasement is applied over the thigh and leg. Four to six week immobilization favors firm adherence of the cartilage, and use is the cautiously permitted after the patient has been warned to put n strain on the internal lateral ligament. He is instructed to walk wit the toes turned in, and the shoe sole is raised on the inner side.

Operative treatment should not be advised for primary luxation Arthrotomy is indicated for repeated luxations, especially those whic are followed by joint effusion, and in the cases of individuals to whom a sudden locking of the joint may be dangerous on account of occupa- tion or other activities. A sudden painful fixed position of the kne might cost the patient's life, if it overtook him at a moment when the movement was demanded to avoid threatening dangers.

Operative treatment for removal of the loose or fractured cartilage is performed frequently and gives the only hope of complete cure. Mr. Robert Jones has performed over 500 arthrotomies on the knee with very few untoward results. A strict asepsis is necessary, and the operative technic employed in fractures is used. An angular incision two and a half or three inches long is made over the lateral aspect of the joint on the side affected while the knee hangs over the table edge. Deep retraction exposes the cartilage, which can be grasped by forceps and cut off. Only boiled instruments, of course, must be introduced. Attempts to suture the cartilage in place have been abandoned in surgery, the result following excision being eminently satisfactory. The joint is not manipulated during operation lest there be air suction, and the opening is closed layer by layer with catgut stitches. If an unfortunate infection in the skin or superficial layers follows, it rarely passes into the joint. In the hands of experts infection of the knee is almost unknown.

DISLOCATION OF THE FIBULA.

The fibula may be dislocated at either end, the luxations at the lower end usually being a complication of fracture considered under the heading of Ankle Fractures.

Dislocations of the upper end of the fibula are caused by direct violence from kicks, or blows, indirect violence in connection with fractures of the bone in its lower portion, and muscular action of the biceps tendon. Golley[1] reported a case. There are not more than 30 cases in the literature. The head of the fibula may be displaced forward and outward, backward or upward, the direction depending on the cause. A flat surface on the tibia against which the fibula lies restrained by ligaments does not furnish great security, and if the ligaments are widely torn, the head of the bone may be movable in any direction forward to backward. I have seen one case caused

[1] Am. Jour. Surg., June, 1907.

by a kick in a football game. There was no fracture of the bone, but the head could be shoved around into several positions just beneath the skin.

A case of traumatic dislocation of the fibula at the upper end was reported by Klose.[1] The patient jumped or fell on the inner border of the foot and felt pain and noticed swelling over the head of the bone when he tried to walk. There was pain on pressure at that site and on flexion of the knee beyond an angle of 80 degrees. No fracture of the fibula nor nerve complication was present. Reduction was made by dorsal flexion of the foot, flexion of the leg, and direct pressure on the head of the fibula. The cause was supposed to be muscular contraction of the common extensors of the toes, the extensor of the great toe and the long peroneus.

A direct blow on the back of the head of the bone and a fall on the extended and inverted foot may act as causes, either forcing the head forward by direct violence or dragging it out of place by leverage from muscle action on the lower part of the shaft. The fibular head assumes a prominent position forward and outward, and there is pain on pressure over it, or when weight-bearing is attempted. Traction on the biceps tendon may cause pain and abnormal movement of the head of the fibula.

Diagnosis.—Diagnosis is not difficult but is often overlooked. A roentgenogram may fail to show any deformity. The anteroposterior view should be made from directly in front backward, and both legs should be exposed for comparison.

Reduction by direct pressure of the surgeon's fingers is not difficult, but the bone tends to slip out at once on account of the poor retention by the torn ligaments. After reduction the leg should be partly flexed that the biceps tendon may relax, a soft pad should be placed against the head of the bone, and a plaster-of-Paris encasement applied in that position. Fixation in the dressing must last four to six weeks, and use is then possible—the position of the head of the bone being strengthened by adhesive-plaster bands.

Backward dislocations may also be caused by direct violence or wrenches at the knee which tear the external lateral and tibiofibular ligament and allow the biceps to pull the head of the bone backward. The peroneal nerve may be involved. Palpation of the head of the bone determines its position backward; there is tenderness on pressure and pain on walking. Reduction is easy, and the same type of treatment is needed as in forward luxation. The prognosis as to function is excellent. Cases of either type which resist reduction or will not remain reduced can be held in place against the tibia by a nail inserted through a small skin opening.

Upward dislocations belong to the exaggerated type of luxation. They usually accompany fracture of the fibula or of both bones of the leg in which the fibular head has been torn from its ligamentous

[1] Deutsch. Militärarztl. Ztschr., Berlin, 1913, xlii, 911.

attachments and shoved upward by the force acting. An open w
may be present. Reduction of the ankle or leg fracture usually
the upper end of the fibula down into position. If it does no
ankle may be forcibly extended and the fibula forced down by
pressure on its head.

Dislocations of the Lower End of the Fibula.—Pure luxation wi
fracture is extremely rare. Separation of the fibula from the
involves rupture not only of the ankle ligaments but of the tibiof
interosseous ligament for some distance upward. A lateral or u
displacement of the bone takes place and the ankle is thickene
shortened by the pushing upward of the talus between the tw
bones. There may be a concomitant upward dislocation of the
end of the fibula. In a few recorded cases the external malleolu
been displaced backward without fracture.

Diagnosis.—Diagnosis is not difficult, because the malleoli lie
cutaneously and can be completely palpated. Pain is present an
of function. Crepitus may be felt on manipulation of the foot
rubbing of the talus. The roentgenogram shows the diastasis bet
the two leg bones. Exposure of the whole leg is necessary that fra
of the upper part of the shaft may be ruled out.

Treatment.—Reduction is made by direct traction on the foo
pressure on the fibula. If that manipulation fails, the foot ca
strongly adducted during traction, and the external malleolu
be pressed down into position. The after-treatment consists
prolonged immobilization in a plaster splint or encasement like
advised for ankle fractures. No use should be made of the
which causes pain or brings stress on the healing ligaments to st
them.

CHAPTER XXVII.

FRACTURES OF THE CALCANEUS (OS CALCIS).

THE calcaneus in the heel transmits a large part of the body weight to the ground and in addition acts as a lever to the calf muscles. Its shape is irregularly cuboid, and the long axis is not directed exactly forward in a straight line but is forward and lateral. This bone of all the tarsal group has two distinct centres of ossification, that for the posterior extremity appearing at the tenth year, uniting with the rest of the bone soon after the sixteenth year. In this area is attached the tendocalcaneus (Achilles). It has practical importance as applied to fractures (see Fig. 609).

Steindler[1] has made a careful study of the architecture of the tarsus, especially of the calcaneus, and Fig. 610 is an adaptation of the Hoaglund schema of the arch of the os calcis given by him. This bone appears to afford a good example of the inner construction of bones as influenced by their static conditions, in accordance with Wolff's ideas, which have been generally adopted. The Hoaglund construction of the calcaneus assumes that there are two trabecular systems.[2] These are (1) the radiar system as represented by the three sets of lines 1, 2, and 3, which lines of force converge toward the centre of the bone and correspond to the distribution of compressional violence, and (2) the arcuar traction lamellæ, 4, 5, and 6, which represent the pull of the gastrocnemius and plantar musculature.

Occurrence.—In the Cook County Hospital records of 10,702 cases I find 92 instances of fracture of this bone, or 0.86 per cent. Other collections cited by Brind[3] are as follows:

	Fractures.	Calcaneus.	Per cent.
Billroth	663	7	1.1
Tietze	17,000	206	1.2
Drenke (Charité)	1,845	29	1.3
Lemmen (Köln)	3,554	65	1.8
Brind (15 years)	3,460	63	1.82

Avulsion fracture was the first known type, being described by Garenglot in 1720. The next description of calcaneus fractures by Malgaigne, in 1843, gave two varieties: first, compression fractures; second, avulsion fractures caused by muscular or tendinous pull. Other classifications, as Golebrewski's five forms and Hoffa and

[1] Jour. Am. Orthop. Assn., 1913.

[2] Radiografiska Studier oefer Spongioseus functionella Structur i calcaneus. Akademik Afhandling, Upsala, 1903.

[3] Arch. f. klin. Chir., Berlin, Bd. cv, Heft III, S. 603.

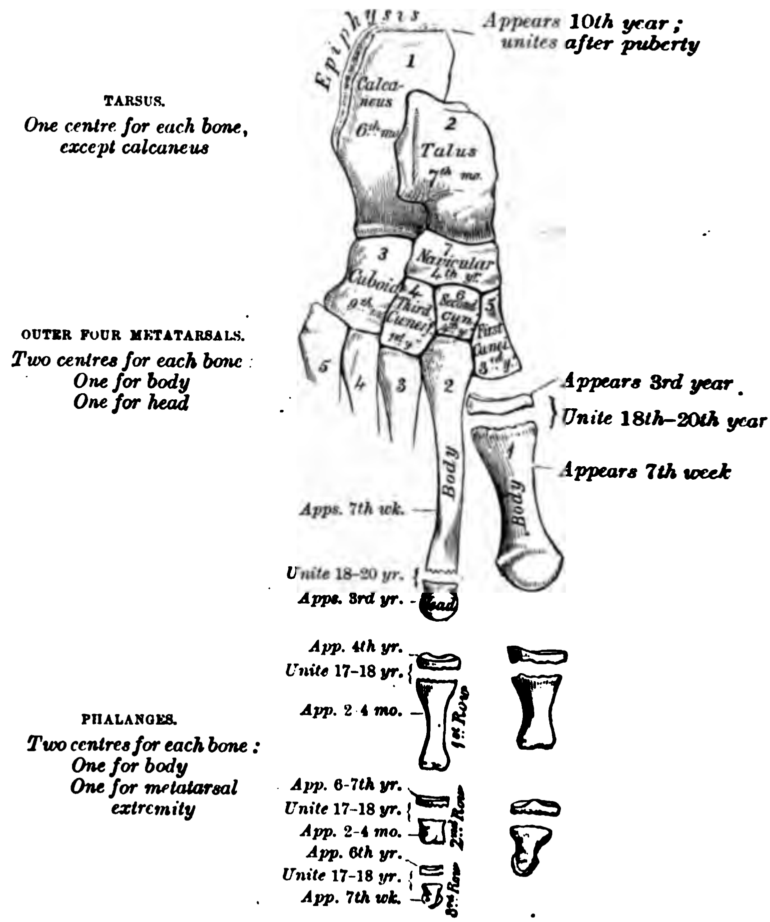


FIG. 609.—Plan of ossification of the foot. (Gray.)

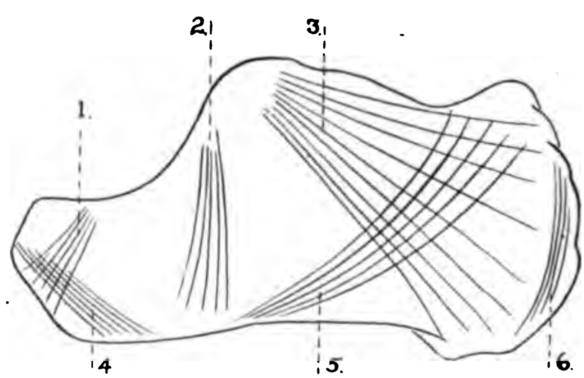


FIG. 610.—Adaptation of the Hoaglund scheme of the trabecular systems in the calcaneus

Schmidt's four forms, are now complete enough to cover our knowledge since the use of the Roentgen rays. These are:

1. Avulsion fractures.
2. Isolated fractures of the sustentaculum tali.
3. Isolated fractures of the trochlear process (peroneal tubercle).
4. Compression fracture of the whole bone.

Avulsion Fractures.—Avulsion fractures of true character are rare and exist with all degrees of separation of the fragments from slight cracks or sprain fractures to complete avulsion and separation of the torn-out piece (Fig. 611). This class is confined to those fractures caused by muscular action as in a person making a misstep off a small elevation, or jumping, or as in one case observed by me when a man's weight was suddenly increased by pressure as he squatted on his

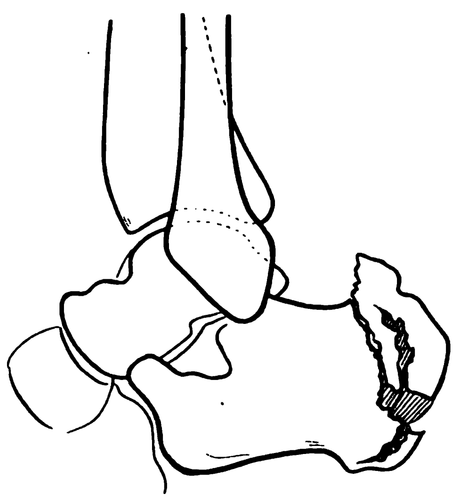


Fig. 611.—Avulsion fracture of the calcaneus. Fragment drawn upward by the calcaneus tendon.

feet, supporting his weight on the buttocks which rested on the heel. The sudden increase of pressure on the calcaneus tendon and the violent contraction of the calf muscles pulled out the shell of the posterior part of the os calcis. Many such separations even in adults take place along the lines of the epiphysis. Fractures caused by pressure of the body weight downward with a line of vertical fracture resulting and the posterior fragment pulled up by the calcaneus tendon are not true avulsion fractures. In the 63 cases collected by Brind[1] only one was due to an avulsion.

Symptoms and Diagnosis.—There is pain and broadening in the heel, loss of function in the foot and a filling in of the hollows about the ankle and heel. If the foot is hyperflexed dorsally when the knee is extended, separation may be seen. Crepitus is frequent. A loose

[1] Loc. cit.

fragment may be both seen and felt drawn up behind the malleolı Hoffa's sign is valuable in diagnosis. It consists in finding that t calcaneus tendon on the injured side is less taut than that on the oth side when the two are compared with the legs in similar position.

Treatment.—The treatment consists in the foot being placed in plaster-of-Paris shoe in a position of complete flexion (plantar). I some instances flexion of the knee permits added relaxation, ar this position must be maintained by a cast which extends onto tl thigh. Five or six weeks in this position result in prompt callus fo mation and bony union, and function quickly returns. Operati procedure may be required. The simplest consists in a tenotomy

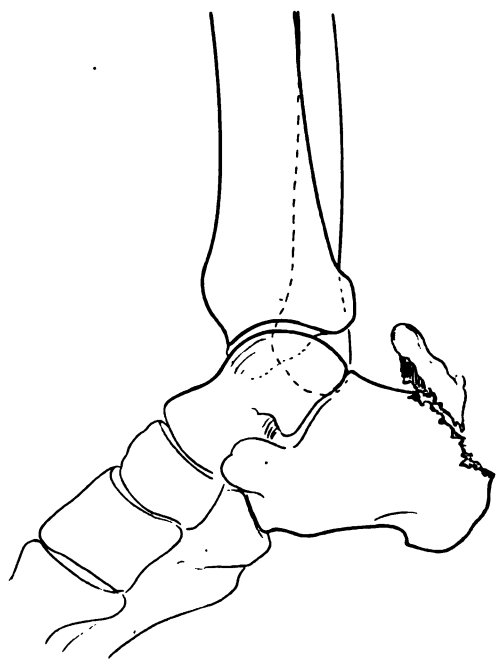


FIG. 612.—A less extensive avulsion fracture with displacement upward.

the calcaneus tendon to permit the avulsed fragment to be replace An open operation may be performed and this fragment reduced int position and nailed, screwed, or wired on.[1] Borchard obtained a goo result in 2 cases by wiring, and Neuschafer[2] fastened 1 by stron catgut with the result that in three and a half months the patien could readily walk upstairs. Tritze[3] believes that open operation i the treatment of choice if there is much displacement, and this i common practice; cigar-box nails or small screws hold admirabl (Figs. 612 and 613).

[1] Gussenbauer, Prag. Med. Wchnschr., 1888, No. 3.
[2] Deutsch. Ztschr. f. Chir., 1899, Bd. l, H. 5 and 6.
[3] Arch. f. Orthop., Bd. vi, H. 4.

Isolated Fracture of the Sustentaculum Tali.—These fractures, which are rare, and were first reported by Abel,[1] who believed they were frequently mistaken for Pott's fractures. They are caused by extreme and forcible inversion of the foot, which later when put into use becomes pronated.

Diagnosis.—Diagnostic signs are: (1) Localized point of extreme tenderness over the sustentaculum; (2) slight displacement of the os calcis forward; (3) the foot in a position of forced abduction; (4) valgus position assumed by the foot in walking. An interesting

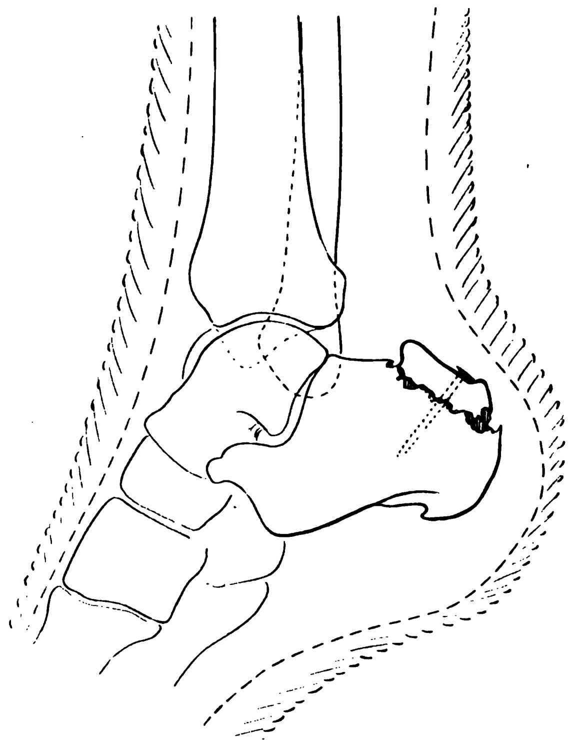


FIG. 613.—Operative repair of the preceding. Note that the foot is encased in plaster in extension to relax the calcaneus tendon.

example of this fracture has been recorded by Skillern,[2] in which a man fell ten feet and the skiagram showed an impaction fracture of the sustentaculum which was driven into the calcaneus.

Treatment.—Treatment consists in immobilizing of the foot in a plaster shoe in slight inversion to permit reunion of the fragments. The cases usually obtain bony union in a short time but may result in permanent deformity and non-union. The metal insole may help strengthen the foot if it does not cause pain by pressure. If a loose

[1] Arch. f. klin. Chir., B. xii, Heft 2, 396.
[2] Ann. of Surg., lvii, 290.

fragment of bone exists, it may require removal on account of] ure pain or interference with tendon action.[1]

Fractures of the Trochlear Process.—These injuries are abo frequent as those of the sustentaculum and are due to direct viol as the calcaneofibular ligament is not inserted in this process dir but behind it, and the pull on the ligament does not affect this point. There is always great pain, and the patient is unable to v and yet the foot does not appear abnormal in any way. Under external malleolus swelling may appear. Brind[2] reports a case w at a point 2 cm. behind the external malleolus there was found a p of bone 2 cm. long by 1 cm. wide which lay parallel to the foot, freely movable, and gave crepitus. The prognosis is good, and tr ment consists in sufficient immobilization to permit bony ur Epiphyseal separations of the calcaneus occur between the age ten and sixteen years and in boys more often than in girls on acc of their activity. They are treated as the fractures of the pro above.

Compression Fractures.—This class composes at least 90 per c of all calcaneus fractures. They are far more common in men t women. Men in such occupation as plasterers, carpenters, s structure workers, or others exposed to falls are liable to this inj Most of the fractures occur in the third and fourth decade, but t have been found in children, or in the aged as late as seventy ye The lines of fracture are of many descriptions, from a faint cı that is difficult to decipher in a good dry roentgenogram to g comminution and mashing of the bone.

Weight-bearing bones which withstand much pressure assum spongy form with the many truss-like trabeculæ crossing at var angles sustained by extra strong bands in the calcaneus as mentic above. This is because the calcaneus with the cuboid and two o metatarsals form the outer arch of the foot which sustains mos the body weight, and we find the compacta of the heel bone is a shell, especially on the lateral and inferior surfaces (Fig. 614). spongy character of the bone endows it with considerable elastic which preserves it from being crushed in falls on the foot by the br ing up of the lines of force exerted by the compression inertia. C pression may also be applied to this bone in injuries which re from force applied laterally to the leg when the foot and knee are fi Experiments to test the compression resistance of this bone h been made by Schmidt,[3] who found that a crunching could be ca by a force equivalent to 150 to 950 kilograms and that a crac break through the bone necessitated a force of 550 to 2000 kg. T fractures are due to falls from a height onto the foot or a he violence applied directly to the sole (Fig. 615). Cabot and Bin studied 111 cases of fracture of the calcaneus and talus which v

[1] Ossenkop, Frakturen des Calcaneus, Inaug. Diss., Würzburg, 1892.
[2] Loc. cit.
[3] Arch. f. klin. Chir., Bd. li, H. 2.
[4] Ann. of Surg., xlv, 50.

admitted to the Massachusetts General Hospital in fifteen years. They found a surprising frequency of these tarsal fractures, 83 occurring

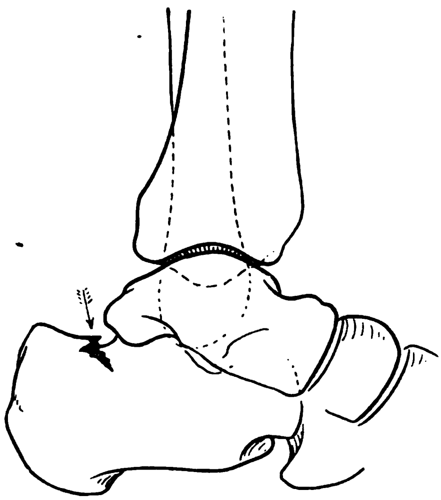


FIG. 614.—A combination of compressional and avulsion violence, incomplete fracture of the calcaneus.

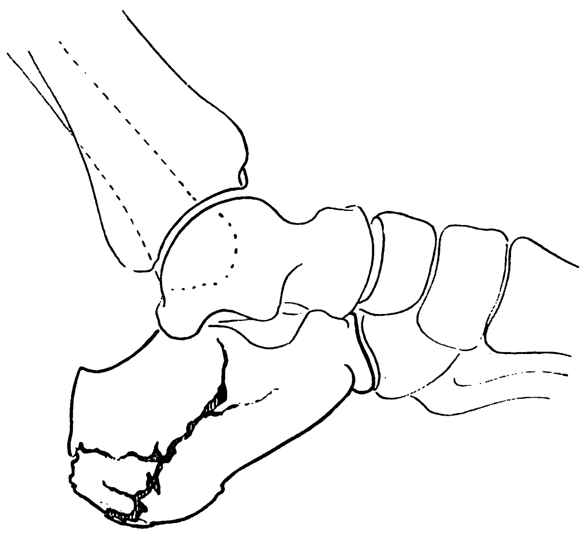


FIG. 615.—Ordinary compression fracture without much separation. No crepitus obtained. This type is often unrecognized and leads to disability.

in the same period of time that 204 Pott's fractures and 396 femur fractures were admitted. In 63 of the 83 cases mentioned the cause was given 59 times as fall from a height.

All had to take to bed, and the disability in the fractures of the talus was much greater than in those of the calcaneus. The gait after use is attempted is characteristic, because the patient holds the foot immovable and always walks on the same point of the sole to avoid pressure pain.

While the prognosis as to life is excellent, that in regard to function of the foot should be guarded, as many cases result in partial disability from painful walking, flat-foot or an acquired club-foot, or painful talocrural joint. These conditions are of prime importance in the working classes and should receive more attention from those treating these injuries. The disability is also enhanced by the muscle changes

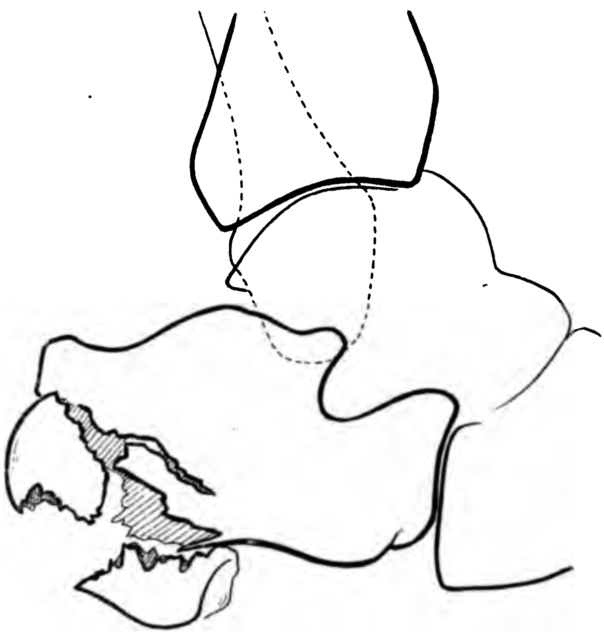


FIG. 617.—Compression fracture with separation of distinct fragments.

subsequent to the pain and the loss of support to the outer arch given by the calcaneus, as described above. Bahr[1] reported 13 cases of calcaneus injury, 6 of which resulted in bad flat-foot and 1 in club-foot. Schmidt,[2] in 14 cases, had 5 flat-feet and 3 club-feet result. Adolescents have a better prognosis than adults or alcoholics.[3]

Probably no foot returns to a normal condition after complete fracture of the os calcis. Cabot and Binney found no case with a normal foot in their series. The prognosis is fair to good in most cases. Results are called good when a foot is painless and useful unless excessive work is demanded of it. Results are called fair in

[1] Arch. f. Orthop., 1903, Bd. i, H. 1. [2] Loc. cit.
[3] Lemmen, Die Brüche des Fersenbeins, Diss. Bonn., 1901.

is applied, following which the patient becomes ambulatory. The cast is removed in four weeks.

After-care consists in massage, hot baths, steaming and electric treatment to strengthen the muscles and foot-joint and to ward off their stiffness. Full treatment takes from three to six months, and the insole and special shoe advised in Pott's fractures should be worn. Tritze says that 24 out of his 76 patients recovered good function, and this is equivalent to good earning power. The cases should be followed faithfully until the final result is obtained. In Brind's series 87 patients, or 43 per cent., obtained 25 per cent. or less use of the foot, whereas 107 patients obtained 30 per cent. or more use.

FRACTURES OF THE TALUS (ASTRAGALUS) AND OTHER FOOT BONES.

The talus is the second largest ankle bone and occupies the keystone position in the ankle arch, resting on the calcaneus below, lying in the mortise between the two leg bones, and resting against the navicular bone in front. Its division into a head, which points forward, a neck, and a body which forms the largest part, is of interest in fracture. It has also on the posterior surface of the body a prominent tubercle of varying size to which the posterior talofibular ligament is attached. This is the posterior process; it may lie separately from the talus. This process is of importance in fractures, because its presence is often misunderstood, and the separate piece of bone appearing in the roentgenogram is diagnosed as a fracture. When so separated it is called the os trigonum.

Because there are several of these supernumerary bones in the foot, knowledge of their presence should be wide-spread in order that errors in diagnosis and medicolegal testimony may be avoided. A very complete atlas of them has been prepared by Dwight[1] from dissection of cadavers, and by the use of the Roentgen rays their presence is verified and their connection with symptoms of pain following trauma can be proved. Geist[2] made a study of 100 normal individuals to determine the frequency of accessory bones which he found in thirty persons as follows, his results corresponding very closely to Dwight's and Pfitzner's figures: Os trigonum, 8 per cent.; os peroneale, 7 per cent.; os tibiale externum, 14 per cent.; os vesalii, 1 per cent.; accessory calcis, 2 per cent.; os intermetatarsum, 2 per cent.; os intercuneiforme, 1 to 2 per cent. (Figs. 618 and 619).

Some of these may have separate centres of ossification; others are freed from the parent bone and become sesamoid in character. All the ankle tendons pass over the surface of the talus, which corresponds to a block and pulley in function, because most of these tendons have grooves in the bone surface in which they play. These tendons cause the motions of flexion and extension of the ankle, and at the

[1] Variations of the Bones of the Hand and Foot, 1907.
[2] Tr. Am. Orthop. Assn., June, 1914, xii, No. 3,

same time the talus occupies the position of transformer of motion in the ankle, acting according to Cotton like a worn

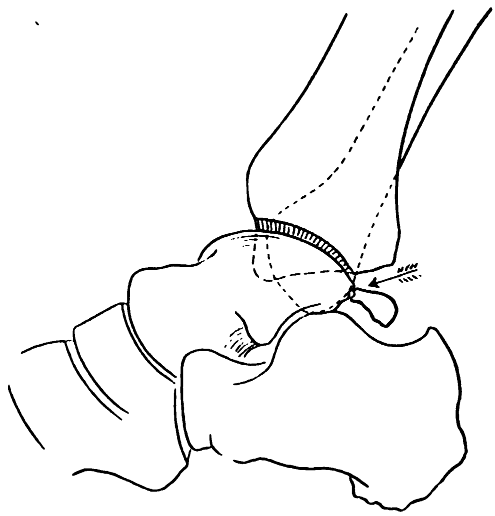


Fig. 618.—Os tibiale externum—compare with picture of fracture of the p posticus tali. This patient gave a history of injury and the sesamoid bone m developed after fracture.

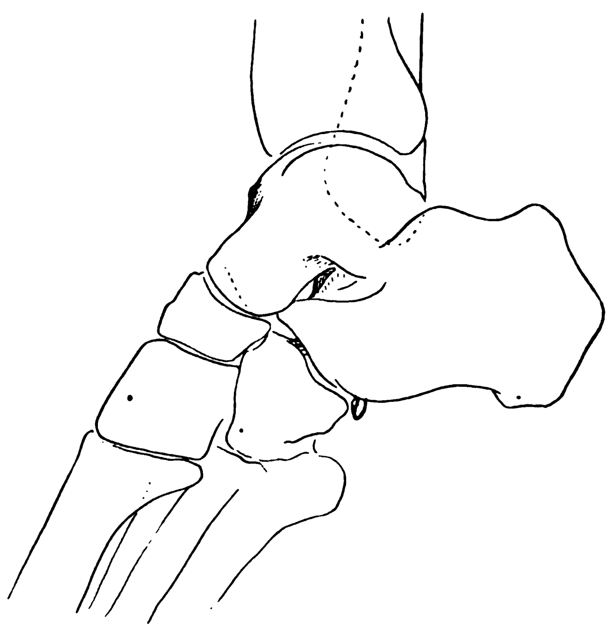


Fig. 619.—Os peroneale.

[1] Am. Surg. Jour., xxviii, No. 1, p. 32.

It has the power of rotatory motion, of pronation and supination which occurs nowhere else in the body except in this tarsal joint.[1]

Fractures of this bone are divided into those of the head, neck, cracks or severe fractures through the body and of the posterior process (Fig. 620). Dislocations and fractures commonly occur together (Fig. 621). In the collection of fractures made by me at the Cook County Hospital this bone was broken in 14 instances. Falls from a height cause crushing of the bone between the tibia and the os calcis beneath, and the heel bone or either of the malleoli may suffer damage at the same time according to the position of the foot and the point of impact.

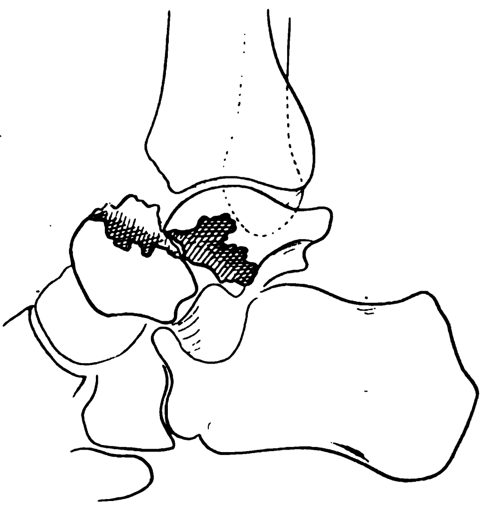


Fig. 620.—Fracture through the weak part of the talus.

Fig. 621.—Fracture dislocation of the talus. Note that the larger fragment is displaced outward.

The talus is fairly protected by its situation between the malleoli and by the crescentic contour of its upper surface. As a consequence the line of fracture varies greatly; the neck alone may break off, the whole bone may be split in its long axis, or it may have transverse and comminuted lines of separation with wide displacement and dislocation of the fragments. Cotton[2] records a case of fall in which the individual sustained the impact on the ball of the foot on one side and the heel on the other with a resulting fracture of the neck of the talus and the os calcis respectively. Gaupp,[3] in 61 cases,

[1] Lovett and Cotton, Tr. Am. Orthop. Assn., xi, 1899.
[2] Joint Fractures and Dislocations.
[3] Beitr. z. klin. Chir., 1904.

found that 45 were caused by falls, and Cabot and Binn
cases, found 21 caused by falls and 14 by direct violence. In t
fractures following falls or jumps, the posterior half is
backward and generally lies just in front of the calcaneu
The anterior portion may be displaced, but in many case
unmoved. The roentgenogram alone shows the pathology,
feet should be exposed for comparison. Even then the evid
be disappointing.

Symptoms.—There is usually swelling of the ankle and m
especially when the foot is dorsiflexed, and if the fragments
minuted and separated, crepitus can be felt with this m
The patient cannot bear weight. And in fracture of this b
the malleoli and os calcis are found on palpation to be in
injury to these latter parts complicates the case, diagnosis ma
difficult. Crepitus, in cracks or fracture with little sepa
great effusion of blood, may be absent, so that the Roen
examination is desirable in all suspected cases.

Diagnosis.—Diagnosis is made by the surgeon feeling crep
finding a normal calcaneus and malleoli, or by feeling the lo
ment of the head or body pushed out of place and appearin
the skin, when accompanied by the evidence of injury as give
Simple cracks without displacement can only be suspected a
be verified by the Roentgen examination.

If no displacement exists, the foot is placed in a fracture
swelling and pain are controlled by an ice-bag. When these
the foot is encased in a plaster shoe in a position at right angl
leg and in direct line of weight-bearing through the ankle
without inversion or eversion. If there is no displacement of fr
Ely advises placing the foot in strong dorsal flexion. Cabot and
examined 8 cases of fractured talus after a year's time. Th
were good in 2 and bad in 6. The length of disability was k
9 of their cases. In 1 it was not in excess of six months, in
six months to a year, in 2 it was twelve to eighteen months
was eighteen to twenty-four months and in 3 it was over two

Where one fragment is displaced and the other is *in situ* the d
portion should be removed; the fixed part may be safely l
good movement with no shortening of the ankle results. If r
is attempted, the skin must be watched for necrosis, becaus
cases become infected, and a persistent osteomyelitis disa
patient for a long time. If the bone is broken horizontally or
comminuted, or part is driven down into the calcaneus, it sh
completely removed by open operation at once. This can
by a lateral angular or curved incision. Hutchinson an
although in favor of operative treatment, do not believe in r
all of the bone. Unreduced fracture of the talus usually shows
thickening about the external malleolus with much pain, p

[1] Loc. cit. [2] Loc. cit.
[3] Tr. Chir. Soc., London, xxxviii, 159.

caused by the low position of this malleolus. The tip may be ankylosed in callus or have a false joint formed about it.

Instances of fracture of the neck with dislocation of the head may be reduced by manipulation or by use of the Thomas wrench. Open operations for reduction of the fragments by simple reposition or nailing do not promise well. Ashhurst[1] reports a case in which the head could be felt anteriorly beneath the skin in its normal position, while the posterior fragment lay beneath the calcaneus tendon with the foot in slight cavus. When the site was opened it was found that the fragments were separated one and a half inches; so both were

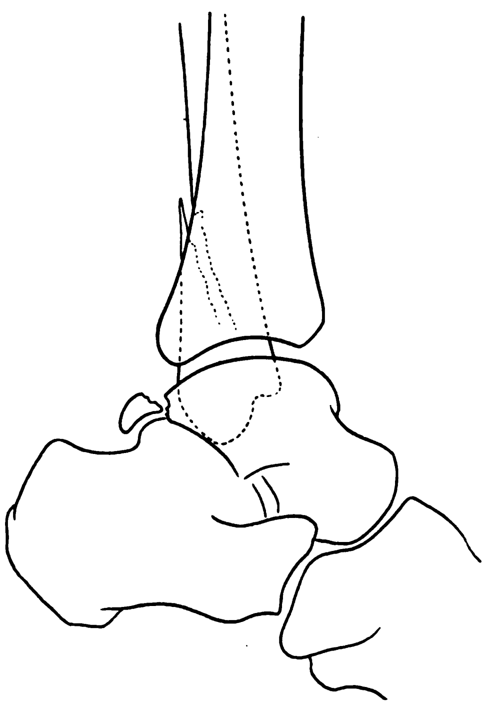


FIG. 622.—Fracture of the posterior process of the talus with accompanying break in the fibula.

removed, the posterior fragment only after a tenotomy of the calcaneus tendon. A plaster encasement for six weeks gave a good result. Old cases with deformity can be treated by a metal ankle brace. Excision of the bone is reached ultimately in most instances.

Fracture of the posterior process may accompany injury to the talus or calcaneus. Fig. 622 represents a fracture of this process without separation, and Fig. 623 a fracture of the process into two separate fragments. The patient had pain and some swelling and tenderness

[1] Ann. of Surg., lv, 120.

on pressure over this area, but diagnosis was possible o
Roentgen rays. A presumptive diagnosis can be made c
tenderness, history of the fall, and pressure above the ex
of the insertion of the calcaneus tendon. Doubtless this p

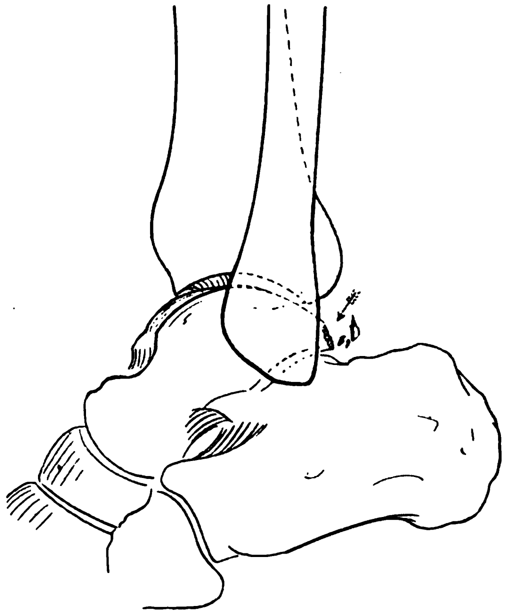


FIG. 623.—Uncomplicated comminuted fracture of the processus pos

be fractured and, becoming separated from the talus, assum
moid appearance in the Roentgen picture. A short period o
ilization should overcome the symptoms, but if they per

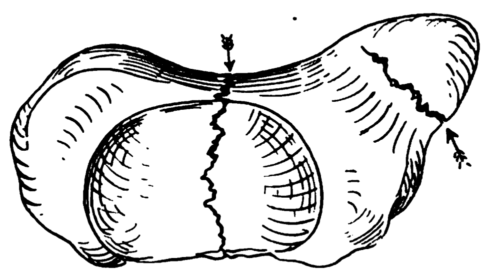


FIG. 624.—Usual sites of fracture in the navicular bone through the tul
through the body.

use of the foot is attempted, excision can be done. Lillienfel
7 fractures of this process in 600 instances of fracture. Five w

[1] Archiv f. klin. Chir., 1905-6, lxxviii, 945.

junction with calcaneus fractures, the mechanism probably being a fall on the heel with the foot in a position of plantar flexion. This position jams the calcaneus against the process.

Fracture of the Navicular Bone (Scaphoid).—This bone lies on the median side of the tarsus between the talus and the cuneiform bones. The plantar surface is rough for attachment of the tibialis posterior muscle, and the median surface presents a tuberosity in which part of this muscle is also inserted (Fig. 624). Routine examination of injured feet by the Roentgen rays demonstrates that this bone is occasionally injured. One collection of 22 cases was made by Finsterer.[1]

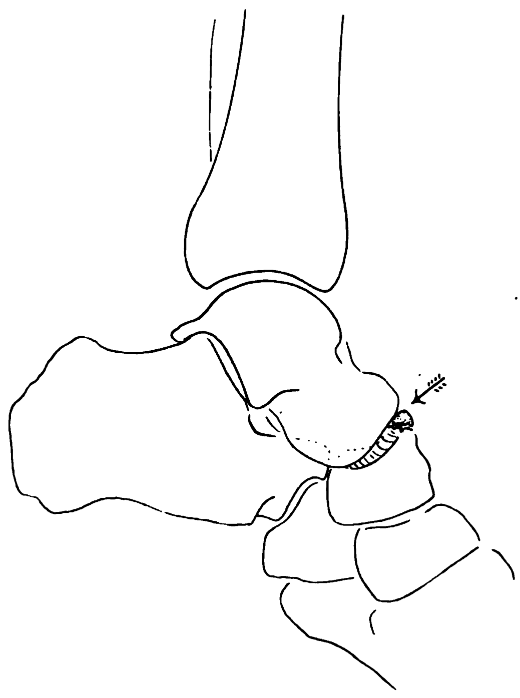


FIG. 625.—Fracture of the tarsal navicular by direct violence.

The bone is most frequently crushed between the talus and the cuneiforms, and though painful, may, even in the Roentgen picture, show little evidence of actual fracture except distortion in shape (Fig. 625). Rarely well-defined lines of separation appear, or two distinct fragments are shown. When violence from falls is received by the foot in forced plantar or dorsal flexion, the navicular bone lies in direct line of transmission and suffers injury. Twists accompanying malleolar fracture at the ankle may also cause the bone to suffer from transmission of force or the pull of the tibialis posterior tendon.

[1] Beiträge z. klin. Chir., lix, 99.

Symptoms.—Symptoms in recent fracture are pain and over the inner side of the tarsus, marked tenderness to press free ankle motion. Midtarsal movements, however, are pai restricted, and the foot is held in slight eversion. If the fr are separated and displaced, they may form a painful prot on the inner side of the foot. Inversion of the foot is greatly In old cases the tenderness over the bone may have largely v but the lack of inversion is noticeable. Abadie[1] reported a fracture of the head of the talus and the scaphoid by com There was much pain in the middle of the foot on palpation o to walk, with an extensive ecchymosis. Roentgen-ray exa is the positive means of diagnosis. Methods of recognition fracture are detailed by Lange.[2]

Treatment.—Treatment in cases of dislocated fragment in strong abduction of the forepart of the foot and pressin fragment down into place. A plaster shoe is worn for thre Macausland[3] reports two acute cases and concludes that t suffers fracture without involvement of the other tarsal bones. the navicular bone is in direct line of weight-bearing and inte with its function disturbs the whole static function of the lir better in comminuted cases that the whole bone be excised su teally and regeneration be awaited while the foot is kept at inversion. The new bone fits the space perfectly and is p by an arch support or adhesive-tape strapping for several Deutschlander[4] says conservative treatment is useless, and Hc recommends excision in old cases.

The presence of the sesamoid os tibiale externum, in the te the tibialis posterior, may cause errors in diagnosis of a small f broken off.[6]

Fractures of the Cuboid and Cuneiform Bones.—These bo be broken by direct violence, and crushed feet examined c by the Roentgen rays show instances of comminution of one bones, frequently in connection with the metatarsals (Fi The dropping of heavy objects on the foot or direct blows fro mers or wagon wheels in runover accidents are the cause. M action may cause a chipping off of a piece of the cuboid, as by Skillern.[7] In this case the left foot was twisted, someth heard to crack, and a swelling immediately appeared at th metatarsal joint definitely localized at the anterior and exter ner of the cuboid. Positive diagnosis depends on the localiz of tenderness with swelling and is to be confirmed by the R examination.

[1] Rev. d'Orthop., 1911. [2] Lancet-Clinic, 1908,
[3] Ann. of Surg., lii, 845.
[4] Verhandl. d. Deutsch. Gesellach. f. Chir., Berlin, 1907, P. 2, xxxvi, 90-100
[5] Beitr. z. klin. Chir., Tübingen, 1908, lix, 217.
[6] Nippold, Arch. f. Phys. Med. u. Med. Tech., Leipzig, 1908, iii, 312.
[7] Ann. of Surg., lvii, 289.

Treatment.—Treatment consists in strapping of the foot as in Skillern's case, in overabduction, or the application of a heavy plantar plaster strip for a couple of weeks when the bones are comminuted. The attendant should recall again the possibility of sesamoid bones confusing the picture and being mistaken for broken-off fragments. The surface of the tuberosity of the cuboid has a facet on which the sesamoid in the peroneus longus tendon glides. Refer to description in Fractures of the Talus.

Fractures of the Metatarsal Bones.—Metatarsal fractures, though relatively common, are often overlooked. They are most often found among laboring men, and are caused by direct violence, such as the

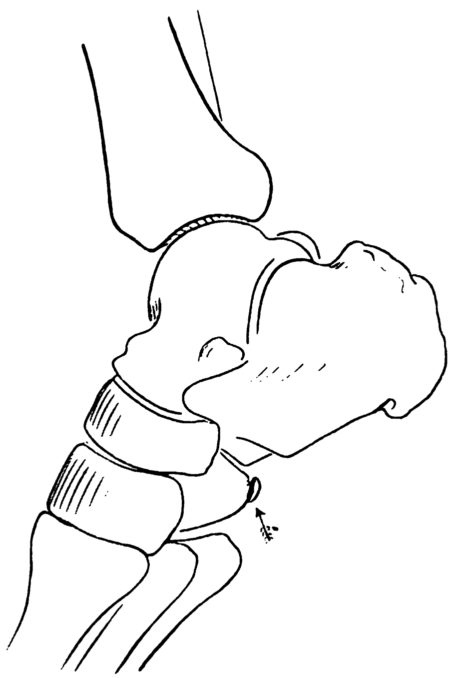


Fig. 626.—Fracture of a cuneiform bone.

dropping of burdens or heavy objects on the feet. Freight handlers, movers, and similar classes are liable to these injuries. On account of the character of the injury and the small amount of deformity a large percentage of the cases are not diagnosed. Indirect violence is also a cause, attention being first drawn to it by Mr. Robert Jones,[1] who fractured his fifth metatarsal across the corner of the base while dancing. Many cases occur in the feet of soldiers or of youths when jumping or playing tennis. Twist of the foot may cause fracture of the *fifth metatarsal*, possibly by pull of the peroneus brevis muscle,

[1] Ann. of Surg., June, 1902.

as reported by Wharton.[1] Lahey[2] watched for fractures of tl osity and proximal end of the fifth metatarsal bone in the City Hospital. In four months' search he found 7 cases (F Lillienfeld[3] observed 5 cases in 600 fractures, and Miller[4] 2 cases. The fracture is not common and is often mistaken for Three different types are found: (1) the plane of fracture pass versely through the proximal end of the bone; (2) it passes the base of the tuberosity; (3) it passes through the tip of tl osity with or without separation.

The mechanism of fracture can be explained by the fact tl cases occur in the act of dancing, jumping, or slipping off

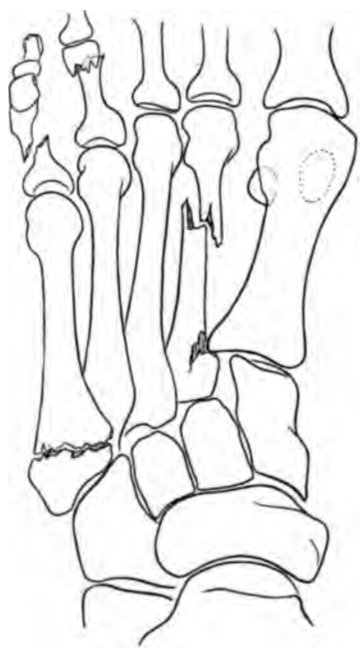


Fig. 627.—Multiple fractures of the metatarsals and phalanges caused violence. Note the transverse fracture of the fifth metatarsal.

height. One of my cases followed a man slipping off the cu as he started to cross the street. The foot is supinated and in flexion. The proximal ends and tuberosity of the fifth me bones vary in size, as has been shown by Dwight. For the fi Lahey is inclined to favor a mechanism of pressure from tl weight directed through the cuboid when the foot is in the su position. This cuboid pressure is counteracted by the ligaments the fourth and fifth metatarsal to the distal end and proba

[1] Ann. of Surg., May, 1908, p. 824.
[2] Boston City Hosp. Med. and Surg. Reports, 16th series, p. 250.
[3] Arch. f. klin. Chir., Bd. lxxviii, 929. [4] Ann. of Surg., March, 19

by the traction on the tuberosity and proximal end of the peroneus brevis. In the second type the cuboid pressure probably acts as the counter-force, the actual cause being the pull of the peroneus brevis. The third type is really a pulling out of the muscle insertion, with dragging of a fragment of bone which in this case is probably an *epiphyseal separation*. A statement is made in Dwight's atlas that this epiphysis appears in about 4 per cent. of the fifth metatarsal bones between the ages of fifteen and eighteen years. Diagnosis is made on the history of the position of the foot at the time of accident and in some cases on the feeling of something giving way on the side of the foot or on an audible snap. There is much local pain with swelling and ecchymosis appearing later. In the first type crepitus may be demonstrated.

FIG. 628.—Fracture through the heads of the first two metatarsals. The sesamoids of the great toe are unharmed.

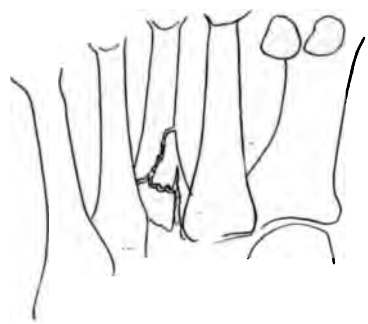


FIG. 629.—Fracture at the base of the middle metatarsal.

The treatment is the placing of the foot in a plaster encasement extending above the ankle. This is left on for two weeks, and the fragment unites readily, leaving no disturbance of function. One case of non-union has been recorded. If a fragment failed to unite it might be nailed on, or, if it caused pain, entirely removed.

In study of the roentgenogram the surgeon must differentiate fracture from the os vesalii, which may be a separate epiphysis or an extratarsal bone lying near the proximal external part of the tuberosity. Coues[1] reports a traumatic case in which the os vesalii was mistaken for fracture of the fifth metatarsal.

The metatarsal bones are so closely packed together and surrounded

[1] Boston Med. and Surg. Jour., clxx, No. 19.

by muscles and the heavy plantar tissues that displacement fracture is not great unless several are broken at the same time (628 and 629). In this case lateral overriding takes place, and us the distal fragment tends to angulate upward. Several bones be broken simultaneously, rarely on the same level, more usuall different points. The line of fracture is commonly transverse or slig oblique; sometimes comminution is present. I have observed t cases of epiphyseal separation in the metatarsals (see Fig. 633).

Diagnosis.—Diagnosis is a trifle uncertain when direct violence been the cause. Swelling and pain in the whole forefoot obscure di findings, and frequently two observers while admitting fractur these bones will not agree on the ones involved. The first metata on account of size and superficial posi can be felt in its whole length, and crep or false motion can be felt when it been broken. If each toe is taken gently moved in extreme flexion and tension, one may feel crepitus of metatarsal connected with it, or there evidenced severe pain when the toe of broken bone is moved. It is sufficient have the history of severe trauma, and find a point of extreme tenderness in or more of the bones by deep pressu and to find pain in the foot when wei is borne on it. The base of the fi metatarsal is frequently broken off, eit obliquely or straight across, and a p sistent point of tenderness or pain sufficient for diagnosis.

Fig. 630.—Fracture at the base of the second metatarsal. Indirect violence.

Infraction or crushing in of the h of the second metatarsal has been cal a typical injury by Freiberg.[1] He repor 6 cases, the majority occurring in you females following trauma in playing ten or stubbing the toe. The symptoms are much like those of flat-fo except that the tenderness is localized at the head of the seco metatarsal bone, where, if of long standing, a thickening of the b can be felt. It is usually unilateral, and the roentgenogram revea in some of the cases small loose bodies free in the joint in addit to the jamming down of the head of the bone. In one case the boc were removed by open operation. The mechanism is doubtless cau by the fact that the second metatarsal bone is longer than the fi and if the flexor power of the great and second toe is insufficient, f cible unguarded impact of the second metatarsal against the grou causes it to be jammed down and broken.

[1] Surg., Gynec. and Obst., xiv, 191.

These fractures are really impacted or egg-shell fractures of the metatarsal head. Skillern[1] reports a case in which the lateral roentgenogram showed an oblique indentation, but no loose fragments.

Treatment.—The treatment consists in the application of a pad to the sole of the foot behind the head of the second metatarsal to elevate the transverse arch and keep it from pressure in walking.

Open fractures of the metatarsals are serious injuries because of the lower resistance of the foot structures, the almost sure infection from dirty skin or the environment of the trauma, and the possibility of gangrene from impeded circulation. The fracture as such is ignored and attention is directed to the point of establishing free drainage and keeping the foot warm and aseptic. Through-and-through openings of the foot are indicated if pus forms. Closed fractures, if of one bone, require a plantar support of a heavy plaster splint, or if several bones are broken with much overriding it may be considered necessary to perform open operation with simple replacement through a small incision on the dorsum of the foot. A plaster shoe well padded under the sole is then indicated. Most trouble and subsequent pain comes from allowing weight-bearing too early. The soft callus yields, and becoming thickened by irritation, causes pain by pressure. Four to six weeks' rest of the foot followed by a felt pad under the sole or a metal insole after walking is started will avoid this trouble. Old cases with pain usually yield to rest and these measures. Once I have removed excessive callus in old fracture for relief of pressure pain.

Infraction is treated likewise, unless the free bodies in the toe-joint grate and are painful, in which event Freiberg advises their removal by arthrotomy.

FRACTURES OF THE PHALANGES OF THE FOOT.

These fractures are caused by direct or indirect violence and may accompany metatarsal fractures. Lines of fracture are usually transverse, although comminution occurs, especially of the distal phalanx (Fig. 631). I have had one case of longitudinal fracture splitting the distal phalanx into four fragments, the other phalanges remaining intact (see Fig. 632). As the phalanges arise from two centres of ossification one for the body and one for the base, joining about the eighteenth year, epiphyseal separation occurs. I have observed several of these, but find no reference to them in the literature (see Fig. 633). A large proportion of these fractures are open, and, as has been stated in the section on Metacarpal Fractures, infection and gangrene are common sequences. Especially is this true of the distal phalanx, which is poorly nourished and has no periosteum, so that it is wiser to remove it early and in entirety if infection extends into the bone. An interesting impacted fracture of the distal phalanx of

[1] Ann. of Surg., lxi, No. 3, p. 371.

the great toe was reported by Beasley.[1] '
the phalanx was driven down on the one
finger end. A small capillary drain in th

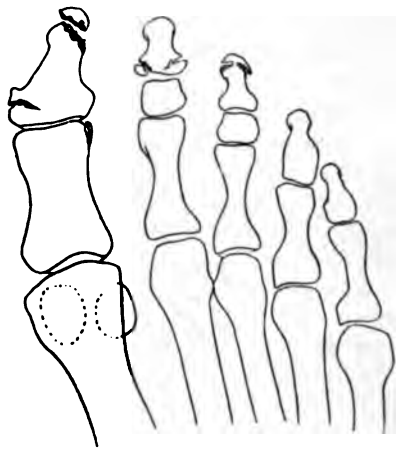


FIG. 631. — Fractures of the distal phalanges. A small corner broken off the second phalanx of the great toe.

F
of t

leads to almost primary union of the open
disability. Infections arising in the toe
lead to serious consequences. All open f

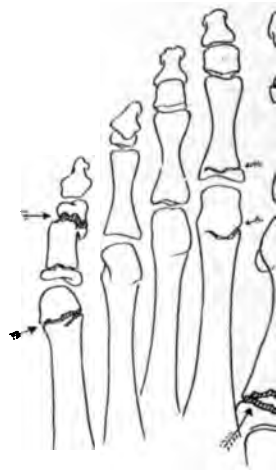


FIG. 633.—Epiphyseal separation of the m

energetically treated, as indicated in the
antitetanic serum should be given.

[1] Railway Surg. Jour., Febru

Diagnosis is usually easy; crepitus and deformity are nearly always present. If there is much swelling and several toes are involved, the Roentgen picture may show cracks and separations of corners of the phalanx where fracture has not been suspected.

Treatment.—Treatment of open fractures is that given in the general chapter. Usually the dressing applied holds the toe in good alignment, or it may be strapped to neighboring toes. This is not so true of the great toe, especially in oblique fracture of the proximal phalanx. If a bandage is run around the dressing, it tends to force the toe laterally so that it comes to assume a position of hallux valgus, and may seriously interfere with walking or be very painful in weight-bearing. Consequently when the great toe is involved it seems best to pay special attention to maintaining it in good position, and a lateral splint of a narrow piece of wood on the median side of the foot will permit the toe to be held straight by adhesive or a narrow bandage. Recently I have had to operate on a toe healed in malposition of abduction, following oblique fracture of the proximal phalanx, because the point of the proximal fragment and the callus pointed out on the inner side of the toe and prohibited shoe wearing.

FRACTURES AND DISLOCATIONS OF THE GREAT TOE SESAMOIDS.

These sesamoids lie in pairs beneath the metatarsal phalangeal joint in the tendon of the flexor brevis hallucis muscle and are more common in males than females and in those of active muscular habits than in sedentary persons. The upper surfaces, which articulate with the grooves in the metatarsal heads, are flat and smooth; the plantar surface is rough. The bones are united to each other and the proximal phalanx by strong fibrous bands. They appear as bone about the eleventh year. Injuries to them are caused by direct violence of a weight falling on the joint, a squeezing of the joint between masses, or in falls when the impact is received in their area, or by a sudden increase in weight-bearing force when one is carrying heavy objects. Most cases are overlooked on account of other more serious injuries, or because no roentgenogram is made.

Sixteen cases were collected by Müller,[1] including 1 of his own, 14 of which were in males, 1 in a female and 1 not stated; 9 were in the right foot, 6 in the left foot; the external or fibular sesamoid was broken in 1 case, the internal in 9; and in 5 there was division of the sesamoid of both great toes, although but one foot was injured. Fracture is differentiated by the finding of the sharp irregular wedge and not a smooth contour. Speed[2] reported 5 additional cases, 4 being of the tibial sesamoid.

Diagnosis depends almost entirely on the Roentgen picture, but a persistent point of pain on deep pressure over the locality of the

[1] Ann. of Surg., lv, 101. [2] Ibid., October, 1914.

sesamoids, following injury, leads to the diagnosis of probab ture. The callus may cause pressure pain by its exuberanc

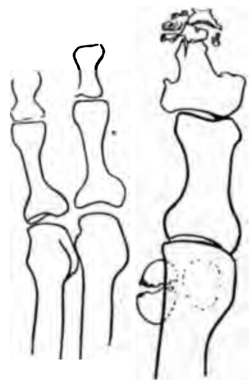


FIG. 634.—Transverse fracture of great toe sesamoid accompanied by fracture of the distal phalanx.

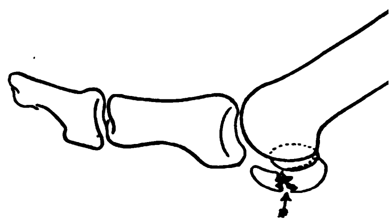


FIG. 635.—Lateral view of a fractu great toe sesamoid.

irritation of the tendon sheath (Figs. 634, 635, and 636). P fracture in bipartite bones must be excluded.[1]

Simple treatment is given by the us circular pad with a centre opening around the bone and worn inside the like an ordinary bunion plaster. C injured bone and its companion m removed. Müller did this in one ca an incision parallel to the flexor hallucis tendon, but an easier appro made by a lateral incision on the oute of the great toe, as I have described. bones must be removed to avoid pr symptoms, which develop if one is left and unsupported. Spontaneous healir doubtedly follows true fracture treat rest and protection.

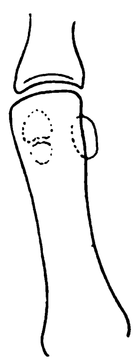


FIG. 636. — Bipartite tibial sesamoid.

I have seen one case of dislocation of two sesamoids following an old posterior dislocation of the grea They caused some pain by pressure in their new environmen this gradually wore off.

[1] References for sesamoid fracture: Schunke, Monatschr. f. Unfallheilk., 1901, Marx, München. med. Wchnschr., 1904, li, 1688; Muskat, Deutsch. med. Wc 1906, xxxii, 1319; Inglestein, Deutsch. Ztschr. f. Chir., 1908, xciii, 505; Mass, Disser., Berlin, 1912; Geist, Am. Jour. Orthop. Surg., 1915, xii, 403; Boardman Gynec. and Obst., xxi, No. 3, p. 394.

CHAPTER XXVIII.

ANKLE AND FOOT DISLOCATIONS.

Anatomy and Landmarks.—In the chapter on Fractures of the Tibia and Fibula the relations and anatomy of the ankle mortise have been touched upon. Practically all motions in the ankle are dorsiflexion when the dorsum of the foot is drawn toward the front of the leg, and extension when the heel is drawn up and the toes are pulled toward the ground. Lateral movements are restricted because the ankle mortise embraces the talus very snugly, and the strong tibiofibular ligaments hold the two leg bones together. The give in the ankle ligaments and the bending of the fibular shaft permit slight motions sideways.

The shape of the mortise and the anterior and posterior lip of the tibial articular surface, aided by the deltoid, posterior talofibular, and calcaneofibular ligaments resist backward dislocations of the talus and ankle. In front the anterior talofibular ligament limits dorsiflexion and aids in restraining the talus from anterior luxation.

Subcutaneous projection of the malleoli makes them the prominent landmarks of the ankle, the outer lower than the inner. The front of the head of the talus can be palpated just in front of the external malleolus, differentiation being afforded by the fact that it moves when the foot is flexed and extended. The calcaneus is palpable on the outer and posterior surfaces, and the long axis of the tibia prolonged passes through the centre of the talus, as previously described. The navicular, cuboid, and metatarsal bones can also be identified in a foot which has not been traumatized, but the quick reaction of swelling precludes exact localization of the bones. Foot length is measured from the end of the great toe to the posterior border of the heel with the tape drawn taut from the hollow of the foot. This measurement is of considerable diagnostic help in determination of shortening of the foot in some dislocations, because it is subject to little variation on account of swelling.

(1) True ankle or tibiotarsal dislocations are rare. Wendel[1] made a collection of 108 cases uncomplicated by fracture of either leg or tarsal bones. It must be admitted that anteroposterior ankle luxation does occur, but in most instances the malleoli or the anterior and posterior surfaces of the tibia are fractured (see Lipping Fracture at the Ankle for statistics, etc.). Lateral luxation at the ankle necessitates fracture or complete separation of the tibia from the fibula, and the talus is not luxated in an exact horizontal displacement but is rotated

[1] Beitr. z. klin. Chir., xxi, 123.

to one side or other on its long axis (see Pott's **Fracture**). The of true dislocations at the ankle which have been reported m classified as forward, backward, inward and outward. Dislo upward is an accompaniment of a severe type of ankle fracture acterized by malleolar fracture, diastasis of the leg bones, an forcing upward of the talus between. Wendel's collection cont four cases of true upward dislocation without fracture. Fo displacement to be effected all ligaments between the talus an bones and the tibiofibular ligaments must be ruptured without damage.

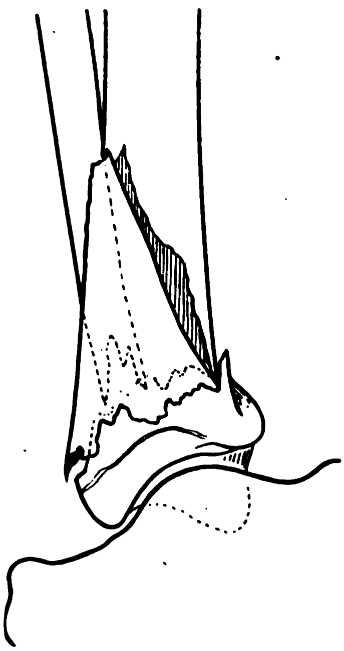


FIG. 637. — False forward dislocation at the ankle. Note that the talus retains its relation to the inferior surface of the tibia, the displacement occurring above at the site of impacted fracture. The projecting lower tibial fragment in front might be mistaken for the talus.

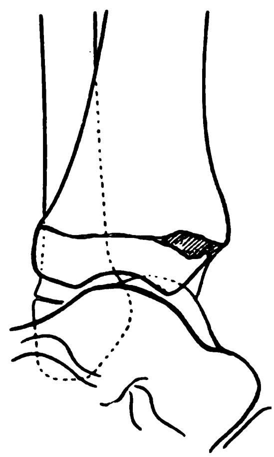


FIG. 638.—Epiphyseal sepa of the lower end of the tibia some displacement of the foot ward. This is a false dislocati

Forward Dislocations.—Forward dislocations are seldom without fracture of the anterior tibial lip. Stimson[1] found 10 c in the literature (Fig. 637). Hyperextension of the foot from f applied to the leg or opposite forces acting, one on the back of heel the other on the front of the ankle, as in squeezes of the f may produce this type of luxation. The heel rides forward an shortened, while the forefoot seems lengthened and lies exten If the case is seen before swelling has occurred, the talus ma

[1] Fractures and Dislocations. 7th ed., p. 892.

felt anteriorly bulging in front of the lower tibial margin. Associated anterior lipping fracture permits more motion than a pure luxation forward. Reduction is easily performed by the surgeon pressing the foot backward, holding the leg above the ankle. A plaster shoe applied with the foot held at a right angle is worn for four weeks.

Backward Dislocations.—The cause of backward luxation is excessive dorsiflexion of the foot, aided by pressure in the long axis of the

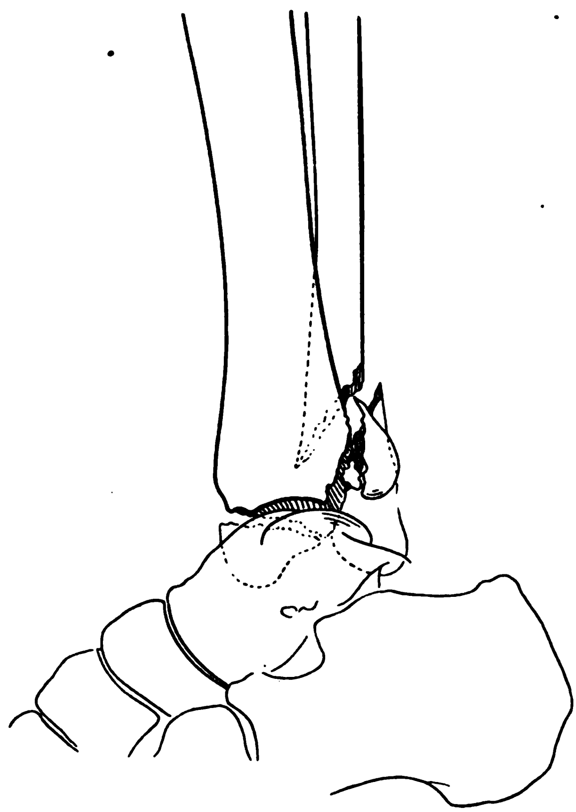


FIG. 639.—Incomplete dislocation backward at the ankle accompanied by fracture of both malleoli and the posterior tibial lip.

leg bones. Lateral and anterior ligaments rupture, and the talus is forced down under the tibial edge and out posteriorly. Most of the so-called posterior luxations are complications of ankle fracture, either Pott's or the posterior lipping fractures previously described (Figs. 638 and 639). If the external malleolus and its ligaments are fractured, we expect the foot to lie in some eversion as well as posterior luxation. Most of these luxations are incomplete or subluxations and but recently have been recognized as complications of the frac-

ture, the true lesion. Heully and Boeckel[1] rep backward dislocation with a fracture of the fibul the malleolus. The lower fibular fragment acc bones (see Ankle Fractures) (Figs. 640, 641, and Cottillon[2] reported a recent case of tibiotarsal l in a thirty-four-year-old man who fell off a ladd swollen, the internal malleolus seemed about to there was bimalleolar thickening. Backward heel for an inch was the striking point in appearai was shortened. The foot was slightly extended from its normal axial line: measurement from th to the point of the heel was 1½ cm. longer on the

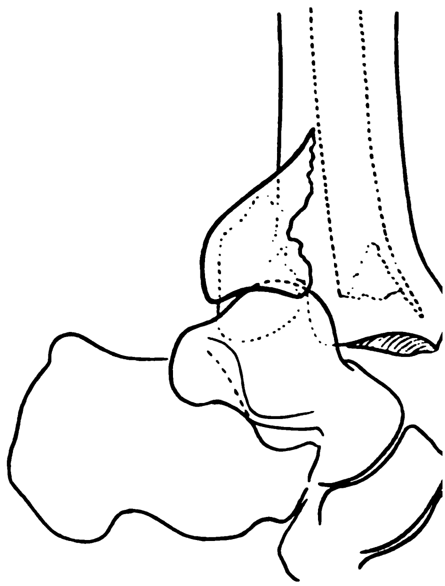


FIG. 640.—Complete backward dislocation with fracture of the p and the external malleolus.

ture of the fibula at the middle third was present were normal. Spontaneous movements of the foo are not possible, and passive movements are both li particularly dorsiflexion. The talus and navic to be normal in their attachments. Open wound the violence, and the lower end of the tibia can be of the ankle-joint. The calcaneus tendon is pull unusual prominence, and hollows form in front of i leoli.

Reduction is made under anesthesia by the a

[1] Rev. d'Orthop., Paris, 1911, 3 S, ii, 249.
[2] Bull. et mém. d. l. Soc. Anat. de Paris, 1912, 6 S,

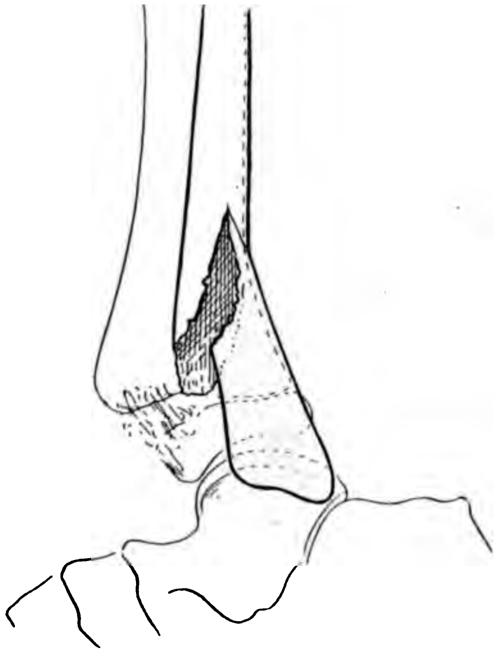


FIG. 641.—Complete backward dislocation with fracture of the external malleolus and epiphyseal separation.

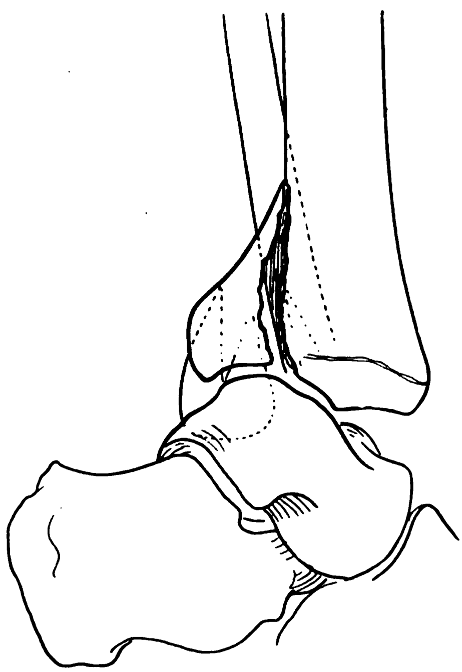


FIG. 642.—Complete backward and upward dislocation with lipping fracture and fracture of the external malleolus.

the heel forward and flexing the forefoot, after which a plaste
or posterior moulded plaster splint is used to prevent the foot
slipping back again.

Inward and Outward Dislocations.—Inward and outward di
tions at the tibiotarsal joint are practically always accompanied by
ture, and the discussion of ankle fractures is intended to cover
(Fig. 643). Many of them are open dislocation, fractures i
ing one or both malleoli or the talus (Fig. 644). They are caus
extreme violence exerted in the mechanism of inversion and ev

FIG. 643.—Complete inward dislocation of the foot at the tibiotarsal joint without discoverable fracture. Note the position of the foot which is outlined at right angles to the leg.

FIG. 644. — Outward dislocation with malleolar ture.

of the foot. Most of the older reports in the literature were not
firmed by roentgenogram, and the scarcity of recent reports con
the ideas expressed on the intimate necessary relationship bet
fracture and dislocation on subsequent displacement. Almost
degree of distortion of the foot may follow torsional strains at
ankle, especially if an open wound results. The sole of the foot
be twisted to an angle of 90 degrees from the normal position. Re
tion is not difficult and the cases are treated from the standp
of open or closed fracture rather than that of dislocation (Fig. 64

Unreduced cases of all types of ankle dislocation may result in sloughing of the soft parts covering the luxated bones. The pathological process is one of pressure necrosis from the bones, superinduced by the trauma on the parts in the causative violence. Formerly primary amputation was frequently advised and performed, but conservative antiseptic treatment is now persisted in because secondary resections of isolated bones or the whole joint lead to a useful foot. After infection is established the joint must be given drainage in both front and rear, and the foot should be prevented from drooping. A resulting ankylosis with the foot at right angles to the leg looks toward a fair functional use.

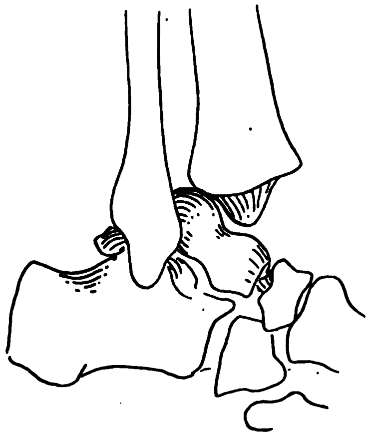


Fig. 645.—Backward and upward foot dislocation without fracture. The tibia and fibula are separated. Drawn from the case of Pakowski and Cotillon.

TALUS DISLOCATIONS.

By this term we understand total dislocations of the talus alone, not of the whole foot with its bones, as described in the preceding paragraphs covering dislocation of the ankle. To establish total luxation of the talus the connections with the tibia, fibula, navicular and calcaneus must be severed; that is, the talocrural and the talotarsal joints are involved. In the discussion of fractures of the talus, its function as a transformer of direct motion between the bones of the leg and the foot was discussed. The mechanism of displacement of the talus is not completely understood, although its luxations are more frequent than true ankle dislocations. It has no muscle attachments, and its displacement probably results from being squeezed out like a pit from a cherry. So numerous are the possibilities of talus injury and displacement that Cotton[1] has described 11 different lesions. No better classification than that of Stimson can be offered, and it is generally adopted.

[1] Am. Jour. Surg., xxviii, No. 1, p. 32.

Talus displacements are (1) forward; (2) outward and forw: (3) inward and forward; (4) backward, and (5) rotatory, the class including those displacements in which the bone still rem: within the confines of the ankle mortise. In 1855 Malgaigne colle 65 cases, and Krönlein, in 400 fresh traumatic dislocations, found n of the talus. A very careful review of the literature was made in 1 by Schmitt,[1] with a discussion of the value of operative treatm Double luxation of the talus was reported by Boyer in 1803, an second case by Sick in 1892.[2] Fracture complicates over one-fi of the cases; Schmitt found 21.1 per. cent. fractured in 95 cases dislocation. In Sick's case the talus was comminuted into four pie Open dislocation is also frequent, 44.2 per cent. in Schmitt's list, the consequences of infection, stiff joints, amputation, and death frequently observed. The posterior tibial artery is occasionally r tured (twice in Schmitt's list) and the posterior tibial nerve has a been reported torn once.

The causes of talus luxation are like those of other ankle injur forced abduction of the foot, falls from heights, and twisting viole when the foot is caught between heavy objects or wheels of vehic the talus suffering as the go-between of the leg and forefoot. Li mentous rupture occurs first, and compression or torsion transmit from above or below forces the bone out of position.

Forward dislocation is rare. The bone is pushed directly forw and may rupture the extensor tendons lying in front. In the few ca reported fracture of the malleoli or calcaneus has been present. F pation discovers the talus in an anterior position turned to any deg in one case the posterior surface looking directly forward. An o wound may be present, and the bone lies free on the front of ankle. Fenwick[3] reported an interesting case of dislocation of *calcaneus* accompanied by a partial *forward* luxation of the ta The patient was an eighteen-year-old boy whose foot was crus between a steamer and a wharf. No pulsation could be felt in foot, which was nothing but a bag of blood. A smooth roun projection could be felt below the external malleolus, but the b prop in the heel was absent. After amputation dissection dem strated that the calcaneus was twisted completely over on its s and the talus was partly dislocated directly forward, the head be tilted up lying on the dorsum of the foot over the navicular. Th were no fractures.

Dislocations outward and forward are the usual luxations, 32 the 95 cases collected by Schmitt. The forefoot is bent inward marked adduction, and the sole is inverted (Fig. 646). A protrus of the talus brings it into a position overlying the triangular bone the outer aspect of the dorsum of the foot, and as many of the ca have open wounds the bone lies in the opening. It may be fractu

[1] Deutsch. Ztschr. f. Chir., Leipzig, 1914, cii, 321.
[2] Berlin. klin. Wchnschr., 1892, 24, p. 580.
[3] British Med. Jour., London, 1911, i, 252.

or displaced in any angle on its long axis. This luxation is probably caused by torsion in forced pronation of the foot, and the inner malleolus is frequently fractured. Active and passive movements are restricted, and the foot is rigid.

Dislocations inward and forward are less common than the preceding type. The foot assumes an opposite deformity, being turned out in eversion and abduction, and the talus is displaced forward and inward, rotated at any angle on its long axis. This type is also frequently an open dislocation, and fractures of the tarsal bones and malleoli may accompany it.

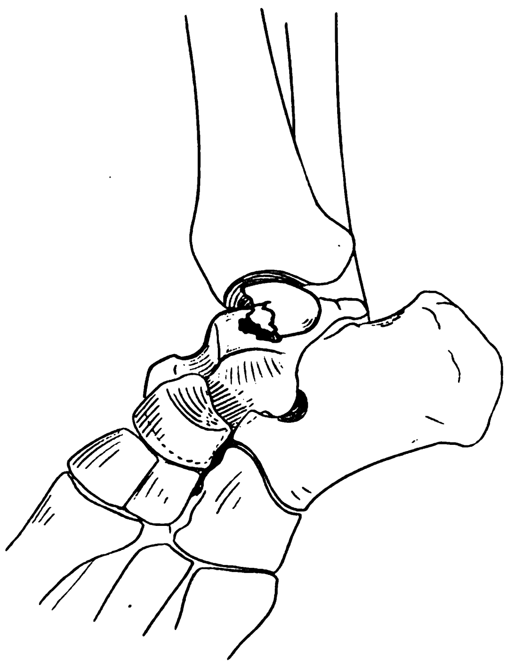


FIG. 646.—Outward and forward dislocation of the talus with fracture. Seen from the inner side.

Dislocation inward is rare. The newer literature contains two cases: V. Bramann's case, referred to by Baumgarten,[1] and Schlatter's.[2]

Dislocations backward have included only part of the bone in most cases. Stimson collected 17 instances, 8 of which had suffered fracture of the neck of the bone with the posterior fragment alone luxated. The bone may go directly backward or to one side and is generally rotated. The tendon groups of the foot are displaced to one side of the bone. By inspection and palpation the talus can be made out back of its usual position pressing against the calcaneus tendon or pointing to one side of it. If the whole bone is luxated, the talus

[1] Dissert. Halle, 1896.

[2] Beitr. z. klin. Chir., 1894, Bd. 11.

is lacking when the front of the joint is palpated and the foot is in dorsiflexion with a depression on the dorsum back of the navicular bone. Reduction is difficult, and the results were not highly satisfactory after manipulative return in the few cases in which it was accomplished. Traction on the forefoot, extension with direct pressure on the talus while inversion of the foot is being made, has accomplished reduction.

Rotatory dislocations do not include those displacements of the talus so common in ankle fractures. Two types of true rotatory luxation exist. In the first type the bone rotates on its transverse axis but still remains within the ankle mortise, and in the second the talus lies in a normal relation to the ankle mortise but has been rotated on its anteroposterior axis. In the first type the bone may be rotated the complete 90 degrees and lie on its side in the mortise; Stimson mentions 7 cases of the second type found in the literature.

Treatment of the Total Dislocations of the Talus.—The older reports in the literature showed that 3 cases in 5 were successfully reduced by manipulation. Probably some of these cases were not pure talus dislocations but were fractures of the calcaneus. In less than half the cases on record either primary or secondary removal of the bone was performed with some secondary amputations and deaths from sepsis. In a few instances the bone remained unreduced.

For closed luxation effort should be made to reduce as soon as possible by manipulation. The Thomas foot wrench is an excellent instrument with which to effect manipulation of the foot in order to aid reduction, because it gives a powerful leverage on the forefoot. The patient is anesthetized, the leg is flexed that the calcaneus tendon may relax, and the wrench is so applied to turn the foot in the direction indicated by the position of the talus, so as to widen the aperture between the bones, and thus enable the talus to be pressed directly back into position. Tenotomy of the calcaneus tendon may be of some assistance. Failure of manipulation indicates attempt at open reduction. Most talus luxations which are not primarily open soon become so, if unreduced, from pressure of the bone on the soft parts, and serious infections are induced. When there is no fracture, open reduction may be accomplished. Roquetta[1] advised open arthrotomy at once rather than leaving of the bone out of position and exposing of the patient to a secondary sloughing of the soft parts. Fracture complication renders removal of the dislocated fragment (if only one is dislocated) imperative. Malgaigne stated that the inferior part of the bone had a richer nourishment than the posterior portion which receives hardly any vessels. The surgical rule at present is to remove the dislocated portion and leave the fragment which is in place. It may necrose, and if it does a second operation is indicated. Schmitt, quoted previously, is in favor of total extirpation after careful review of 95 cases. The foot is not much shortened, and function is fair. Middeldorff's second case[2] had 1 cm. shortening of the foot and Lan-

[1] Arch. gen. de Med., 1883, 8 ii.
[2] München. med. Wchnschr., 1886, S. 929, U. 952.

derer's[1] case 2 cm. after extirpation. Von Bergmann[2] had a patient with extirpation who could run well seventeen years afterward.

Open dislocations depend on the injury of the bone in addition to the luxation. I have seen one without fracture reduced with a fair functional result. When fracture is present, removal of the whole bone is the treatment of choice. In any case when the patient cannot be controlled under good hospital conditions, total extirpation with drainage is best. The foot is held at a right angle during healing. No stitches should be put in the skin wound, but a large aseptic dressing strengthened by a moulded plaster splint should hold the foot, and passive motion is begun in the second week if tenotomy has not been performed. Weight-bearing is prohibited for six to eight weeks and then is permitted in a closely fitting ankle support. The results after reduction of closed luxation are satisfactory, and the foot may return to a normal condition. A similar statement may be made of uninfected open reductions, but the infected cases lead to prolonged disability and frequently to amputation. From a limited experience in recent dislocations but a broader one in secondary operations on the infected bone, I am inclined to favor immediate extirpation with wide drainage. Expectant treatment of the unreduced bone is to be condemned; it may lead to serious sepsis. Functional results after extirpation are not startling, but the patient is able to be up and around and does not usually need the repeated operations for infected bone and the long course of repair with its necessary inactivity.

A unique case of supposed luxation downward of the calcaneus was reported by Horand.[3] The patient was a fifty-six-year-old man who had sustained a fracture of the external malleolus, and the calcaneus was found standing at a right angle. Destot and Gallois[4] investigated the case and found that the position was really an acquired pes calcaneus caused by a leg paralysis which had lasted forty-eight years instead of a recent injury of three months reported by the original writer. The only case of calcaneus luxation I can find is that of Fenwick, mentioned previously.

SUBTALUS DISLOCATIONS.

These luxations embrace those occurring below the talus, a bone which remains in more or less normal relationship with the ankle mortise. Luxation of the foot, including the calcaneus, necessitates a freeing of the tarsal navicular and cuboid, plus freeing of the calcaneus from the talus and a maintenance of their relationship to each other after the lone tarsal bone is left in the ankle-joint. Possible displacements are divided into four varieties. Inward and outward are the most common positions, inward being the ordinary finding.

[1] Zentralbl. f. Chir., 1881, S. 609.
[2] Arch. f. klin. Chir., 1893, Bd. xliii, H. 3, S. i.
[3] Lyon Méd., 1912, cxviii, 1289.
[4] Lyon Chir., 1912, viii, 311.

A few rare instances of luxation forward or backward have recorded.

Inward subtalus dislocations are caused by forcible inversio adduction of the foot received by violent twists or falls whe body weight forces the leg down on the adducted foot (Fig. The cuboid and calcaneus are displaced inward and generally a backward, so that the head of the talus overrides the cuboid. ture does not often accompany this luxation. The dorsum c foot is shortened, and the malleoli are found in normal relation palpation, but the inner malleolus is more prominent. All the

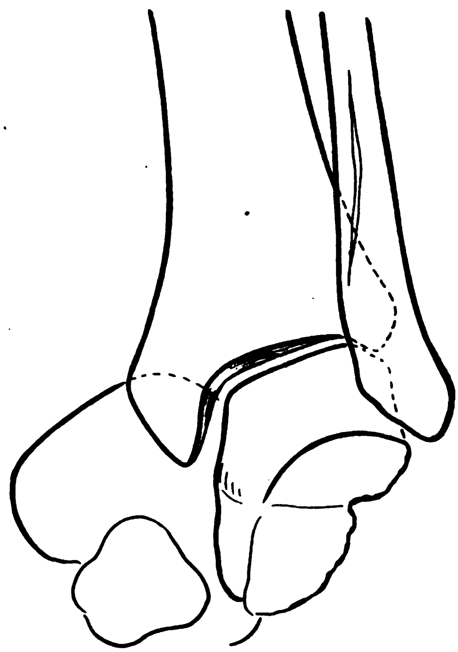


Fig. 647.—Subtalus dislocation inward. There has also been a fracture, bu impossible to isolate it more clearly in the rœntgenogram.

are drawn into adduction. A projection caused by the head c talus anteriorly is the important point in diagnosis. If swellin not obliterated the findings, the head can be felt and seen sti outward away from its position next to the navicular. The calc seems twisted and lies at the same angle as the rest of the foot the sustentaculum tali may be palpated beneath the skin on the side of the bone. Differentiation must be made from bimal fracture at the ankle and fracture of the talus with lateral displace Intact malleoli, palpation of the head of the talus, lack of cre and the rigid inversion of the foot with shortening of the dorsum c lish a diagnosis. Roentgenogram should be made for confirm

and for establishing presence or absence of accompanying fracture. Mediotarsal luxation is also confused with this dislocation.

Outward dislocation is caused by force acting on the inner side of the foot displacing the bones outward instead of inward, as described in the preceding type. The talus remains in the ankle mortise, the cuboid and calcaneus are pushed outward, and the talus appears as a prominence on the inner side of the foot with a depression in front of it. Abduction of the toes is present, and the internal malleolus is prominent and nearer the ground, the external malleolus being lost in the tissues displaced with the calcaneus. Before swelling has ensued the navicular may be felt on the outside of the anteroposterior foot axis with a depression behind it. Varying degrees of obliquity of the foot are possible, and fractures of tarsal bones or diastases between them may also be complications.

Dislocations backward and forward are extremely rare. In the backward type the navicular is depressed to lie beneath the talus, the calcaneus is drawn back and up to lengthen the heel, and the foot is in extreme extension. The forefoot may be angularly displaced. The malleoli are prominent and in front of the joint the talus sticks out as if it would burst through the skin. Rigidity of the foot and a shortening of the distance from the inner malleous to the tip of the hallux are additional symptoms. Forward dislocation gives the reverse deformity. Lengthening of the dorsum of the foot and shortening of the heel are present. The malleoli seem to be in contact with the calcaneus tendon, and beneath the tense extensor tendons on the dorsum of the foot no bony prominences can be palpated. The posterior articular lip of the tibia may be plainly felt beneath the calcaneus tendon. Palpation and roentgenogram exclude fracture.

Diagnosis.—General diagnosis of subtalus luxations depends on finding the talus in normal relation with the leg bones and not with the tarsal bones. The calcaneus is also in irregular position, but corresponds to the location of the rest of the foot. Extension and flexion at the tibiotarsal joint are not interfered with, but the rotatory movement in the joint below the talus is either inhibited or exaggerated.

Treatment.—Reduction is attempted under anesthesia after fixation of the ankle, the knee also being flexed by an assistant. The surgeon exerts manual traction, pulling with one hand on the heel and the other on the forefoot, and swinging the foot around to meet the conditions of displacement. For inward luxation the foot is swung outward, for outward luxation, inward. Direct pressure on the anterior surface of the ankle downward may assist the reduction, which is generally easy and accompanied by a satisfactory jar as the bones slip back. Manipulation failure will be an indication for open reduction, which permits incision of restraining ligaments, the untangling of tendons, and the use of metal levers to pry the bones into position. Open luxations must be reduced as soon as possible and then cared for like other open wounds. Infection, gangrene, and uselessness of the foot indicate amputation.

Prognosis.—The prognosis after reducti
a case of recurrent talus luxation. The
lems, and primary amputation may be i
be made. With closed cases use of the
after reduction, and the ultimate functi
records has been excellent. Irreducible
infection or gangrene finally regain som
deformed and use is greatly limited.

MEDIOTARSAL DISLO

Luxation at the mediotarsal joint occ
cuboid and navicular bones away from t
talus and calcaneus. Malgaigne made
of the luxation at this joint in 1855.[2]

The transverse tarsal or mediotarsal
talus and calcaneus behind and the cuboi
is supported by the strong plantar ligam
of the peroneus longus tendon. The ca
while the talonavicular joint, which lies hi
latter joint is for the head of the talus,
sustentaculum tali behind, the navicula
by the extremely strong inferior calcane
is further braced by the insertion of t
Motion in the mediotarsal joint as a wh
of the two joints described and consists
the plantar surface and some rotation
axis.

Dislocations in the mediotarsal joint
total, according to whether one or both
involved; complete and incomplete; and
to the direction the peripheral bones ta
part of the foot between the talus and cub
The initial separation takes place betwe
and separation of the second part of the joi
the literature for all cases of mediotarsa
could select a total of 34.[4] Mueller[5] ap
roentgenogram to mediotarsal luxations a
12 cases. Skillern[6] has added 1 case. R
by Goebel,[7] whose case was practically
navicular and internal cuneiform alone, a
year-old girl, reported by Corson.[8] I ha

[1] Dislocations and Joint Fractures, p. 603.
[2] Traité des Fract. et des Luxations, ii, 1071.
[4] Petit, Oeuvres Comp. Biblio. Chir., 1837, i, 98
1853, T. iii, 566; Cooper, Treatise on Fractures and
[5] Fortschr. a. d. Geb. der Roentgenstrahlen, 1911
[6] Tr. Philadelphia Acad. Surg., xvi, 58.
[8] Ann. of Surg., 1912, lvi, 883.

roentgenogram in this case and cannot see that it shows any subluxation.

The causes are direct and indirect violence from hyperextension of the forefoot. It may be that repeated sprains and hyperextension injuries of the foot predispose to this luxation by relaxing the ligaments and inducing flat-foot. After dislocation the foot is rigid, swollen, and has complete loss of motion below the ankle. Shortening between the inner malleolus and the end of the great toe is constantly present. When the luxation is dorsal, the navicular is seen and felt displaced upward and onto the dorsum of the ankle in the partial type, and the cuboid accompanies it if the luxation is total. On the plantar surface the anterior edge of the calcaneus is correspondingly prominent. Plantar dislocation is more frequent. The cuboid and navicular are displaced downward into the sole of the foot, obliterating the arch and causing a bony projection there. On the dorsum of the foot the head of the talus and the anterior surface of the calcaneus form a bony protuberance, and over this ridge the extensor tendons can be seen and felt drawn taut.

Treatment.—Treatment is immediate under anesthesia by dorsiflexion or extension, according to the displacement, aided by direct pressure on the talus. Associated lesions of fracture, especially of the calcaneus, must receive attention. Early reduction avoids adherent tendons, loss of foot function, and a filling in of the joint surfaces left bare by the luxation which follows after non-reduction. The prognosis is good after prompt reduction. The strong ligaments of the foot are not torn, and the arch is not weakened. Irreducible cases or old cases can be improved functionally by tarsectomy, the operator removing the navicular and restoring the forefoot to a weight-bearing axis after reëstablishing the arch. The foot is weakened and will need an arch support after weight-bearing is begun. Cotton[1] records an open reduction of an unrecognized dislocation of a year's standing in a forty-six-year-old woman. Open reduction was performed, not for pain, but for clumsiness and uncertainty in use of the foot, induced by its marked inversion.

DISLOCATIONS OF ISOLATED TARSAL BONES.

Dislocations of isolated tarsal bones are not the rarity they have been considered. Examination by the Roentgen rays of traumatic injuries is bringing more reports of these luxations into the literature, and a classification of them will slowly be established.

Calcaneus dislocation was mentioned under the discussion of subtalus luxations. Canton[2] reported a case which he discovered in a cadaver. The calcaneus was displaced outward with the anterior end of the external malleolus lying between the navicular and cuboid.

Navicular dislocations are more frequent. In 1910 Boeckel[3] pub-

[1] Dislocations and Joint Fractures, p. 607.

[2] Lancet, 1847, i, 505.

[3] Rev. de Chir., Paris, 1910, xxx, 102 and 280.

lished an extensive article on these dislocations, reporting Gross's an Weiss's cases from the clinic at Nancy. The navicular bone articulat with six neighboring bones, the calcaneus, talus, cuboid, and thr cuneiforms, with the strongest ligamentous support on the plant surface. Both the plantar and dorsal muscles and tendons help hol it in place. Luxations of the navicular are divided into navicul cuneiform separations, of which there are 16 cases recorded; tal navicular separations, 17 cases; and total separations, seen whe the navicular loses all connections with the surrounding bones. (the last type there are 10 cases, and I am able to add another (se Figs. 648 and 649). The navicular offers support to the blows receive

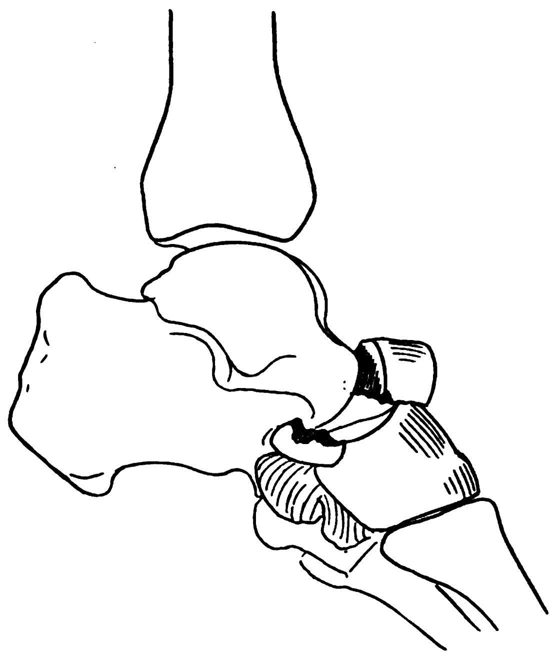


FIG. 648.—Total dorsal dislocation of the navicular. Fracture of the tuberosity. Lateral view.

from the talus in falls, but on account of the slight angle of declination of the talus, which does not point directly forward, there is a struggle between the two bones (Fig. 650). The talus wishes to pass downward but is prevented by the navicular. It cannot go inward, because it is blocked by the tuberosity of the navicular, and there is consequently a luxation of the talus downward and inward, or of the navicular upward, frequently accompanied by fracture of the bony points. Destot[1] calls this a traumatic flat-foot and assumes that the primary actor in the displacement is the talus, the navicular acting merely as

[1] Lyon Chir., 1898, iv, 495; and Rev. de Chir., 1898.

a tampon, the queue of the fan formed by the three first metatarsals. He considers subtalus dislocations triple talus dislocations, inasmuch

FIG. 649.—Anteroposterior view of total dislocation of the navicular. Note the broken-off tuberosity.

as the latter bone leaves its connections with the tibia, calcaneum, and navicular (Figs. 651, 652, and 653). Destot states, without giving

FIG. 650.—Total dorsal dislocation of the navicular. The ridge in the soft parts was caused by a strap the patient used to hold his slipper on.

any details, that he has seen a great number of navicular dislocations in the last fifteen years, and he considers that the term navicular

dislocation should be applied only to tc
also that navicular cuneiform luxation shc
luxation. An instance of double dislocati
The patient was a thirty-two-year-old ı
extended position, and there was much sv
nosis of fracture of the calcaneus was m:
showed in the right foot a luxation of the
ture and periosteal elevation of the edge
showed complete uncomplicated upward

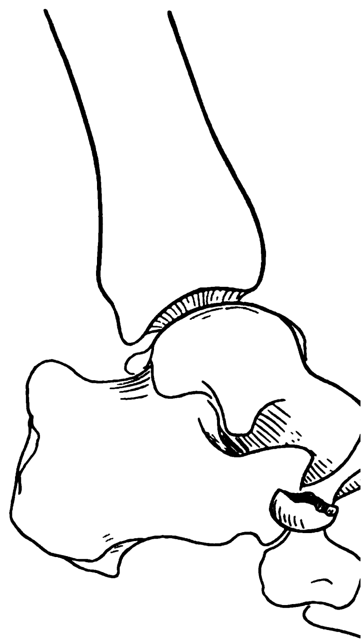


FIG. 651.—Lateral view of ankle after removal of
fragment remains

An open operation was performed, and
nailed to the talus. Infection followed, aı
with one-third normal function. Linhart
downward, the navicular in one foot beiı
external malleolus. Boeckel's report of
one of the best in literature. Both patieı
six and nineteen years respectively, who
wagon wheel passing over them while they

[1] Deutsch. Ztschr. f. Chir., Leipzi
[2] Wien. Med. Presse, July 12, 1868

extension and supination. There was great swelling, and a hard, bony protuberance was felt on the dorsum of the foot. One had an open wound (Gros), and the roentgenogram showed fracture of the

FIG. 652.—Anteroposterior view of foot after removal of navicular.

external part of the cuboid and tuberosity of the fifth metatarsal, the navicular being completely luxated upward into the neck of the talus. Walking and all movements of the foot were very painful.

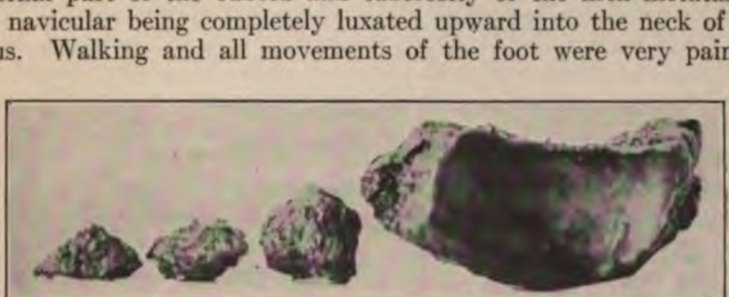


FIG. 653.—Removed dislocated navicular. The surface articulating with the cuneiforms is turned forward.

In the case of total upward dislocation which I had, the patient could walk quite well. The following is an enumeration of the cases of navicular luxation to date:

joint may follow; Cuboid dislocations are practically unknown. Bell[1] reported one case of displacement in connection with the fifth metatarsal. It was reduced.

Cuneiform dislocations are more common, all three going out of place together, or the first one alone. Lemoine[2] collected 4 cases of the latter type, most of which were upward and inward. The first metatarsal may move with the cuneiform, flattening the arch of the foot. Other cases of dislocations of the second cuneiform, or all three together, appear in the literature, usually before the Roentgen period and without definite information of accompanying lesions. Reduction is made by traction on the toes and direct pressure on the luxated bone. Dislocation of isolated bones is more difficult to reduce than that of groups of bones and excision most often is resorted to.

DISLOCATIONS OF THE METATARSAL AND PHALANGEAL BONES.

Dislocations of the metatarsal bones at Lisfranc's joint are fairly common. In 1904 Bayer[3] collected 68 cases, 34 of which were complete and 34 partial. Twenty were dislocations of single bones with the following frequency:

First metatarsal, 9 cases upward, 3 downward, 2 inward; second metatarsal, 1 case upward; fourth metatarsal, 3 cases upward; fifth metatarsal, 1 case outward, 1 downward.

Isolated luxation of the third metatarsal has not been reported. A later collection in 1910 by Grunert[4] contained 113 cases, 58 total, 55 partial, 14 of the total number having been treated by operation. Only 4 cases were in women, and falls from a horse with the foot caught in the stirrup or under the horse was the most frequent cause. Hermann[5] reported 2 cases, the first in a forty-two-year-old man who was climbing a ladder when a rung broke, dislocating his first four metatarsals upward but leaving the fifth in place. There were no fractures. The second one was in a nineteen-year-old boy; a 50 kg. weight fell on his whole foot, dislocating the second metatarsal upward without fracture. Reduction and casts gave good results in these cases within six weeks.

Most of the dislocations are caused by direct violence and are not often complicated by fracture, but there may be fracture of any of the individual metacarpal or carpal bones. The causes in Bayer's collection were springs or falls on the foot, 13; fall of heavy objects on the foot, 14; horse stepping on foot, 11, and so on. Among the 68 cases 9 were not replaced. There was a good result in 30, 26 had poor

[1] New York Jour. Med., 1859, p. 329.
[2] Rev. de Chir., 1883, iii, 118.
[3] Sammlung, Klin. Vorträge, N. F., No. 372.
[4] Deutsch. Ztschr. f. Chir., Bd. xcii.
[5] Beitr. z. klin. Chir., Bd. xciii, No. 1, p. 182.

position, and of 7 operative repositions
made the following compilation of the re

	Collectio
Bayer	68
Lenormant	96
Grunert	113
Quenu and Küss	34
Hermann (cases since 1911) . . .	16

Dislocation of the first metatarsal is
along the line of this bone that the we
Quenu considers this bone so important
two planes, the inner one containing t
metatarsal, the outer one the other me
subdivision is of practical importance.

Symptoms.—A typical case such as re
taken. A young man was riding a horse
the rider's leg beneath. The foot, whic
extension in the stirrup, was violently a
not walk; his foot was in a valgus positio
On the plantar surface the foot was swo
head of the metatarsals, and the intern
shortened as compared with that of th
the tibiotarsal joints were normal, but
outward. The skin on the dorsum of tl
and Chopart's and the tibiotarsal joint
gram showed a plantar luxation some
metatarsal. Reduction was made by t
plantar pressure on the first metatarsa
fifteen days, and the result was excelle
in equestrians when the horse falls are
of the man's body falling from the hor
the horse's weight falling on the rider's
Partial luxations involve the first meta
are plantar. They are not difficult to red
Chaput[4] reported an incomplete upwa
of the first metatarsal. A heavy weigh
fracturing the third and fourth metatar
The mobility of the toes was greatly dir
at the tarsometatarsal line and the first
and outside the external border of the
and third cuneiforms gave some evidence
gram. The mechanism seemed to have
extremity of the metatarsals downwar

[1] Lenormant, Arch. Gen. de Chir., Paris, 1908, N
1909; Brockmann, Deutsch. Ztschr. f. Chir., Bd. c
et. mém. d. la. Soc. Anat. de Paris, 6th series, T. :
[2] Loc. cit. [3] Arch. de méd. et
[4] Bull. et mém. d. l. Soc. de Chir. de Paris, 1912,

end of the bones. At the same time the cuneiforms were compressed from above downward. The two forces acting in an oblique direction caused the dislocation and carried the metatarsals outward.

Total luxations of the metatarsals are grave injuries, and almost all of them are dorsal. One type, with or without fracture, is the divergent dislocation, with a diastasis of the first intermetatarsal space, the first metatarsal being displaced inward, the other metatarsals outward or out and upward. Quenu terms this the spatular type. The total dislocations, especially the divergent type, should be reduced at once, by traction on the toes. If swelling has already occurred, a total luxation may be put at rest with ice-bags and a reduction made later under anesthesia. Divergent dislocation should be reduced at once, especially the first metatarsal displacement. If traction fails, open operation should be performed for reduction of this important bone; the others can be reduced later by manipulation, or if they remain unreduced the function is fair. In any isolated irreducible dislocation of the metatarsals, or in recurring dislocation, the bone may be resected or nailed into place, the operation followed by the application of a plaster dressing to be worn for four or five weeks. Young[1] reported three metatarsal luxations, two complete outward dislocations in which the forefoot was abducted and everted and the internal cuneiforms stood out prominently on the inner side of the foot. The reductions were easy, and after the foot was placed in plaster in slight adduction and inversion for three weeks the anatomical and functional results were good. His third case was a divergent dislocation, the first metatarsal being displaced completely inward, projecting under the skin on the inner side of the foot, and the others, except the fifth, being dislocated outward with some comminution of the bones. Reduction was made under anesthesia. Other divergent dislocations have been reported by Petit,[2] Walther,[3] Tuffier and Lenger.[4] The roentgenogram is quite necessary for positive diagnosis, but one can be made clinically on discovery that the forefoot forms an obtuse angle with the back foot and an angular deformity at Lisfranc's joint on the internal margin. A globular thickened shape of the dorsum, the tense extensor tendons of the toes passing over this mass, and widening of the internal border of the foot with an imprint of the wet foot which shows that the weight is carried in walking on the outer side, are presumptive evidence. On the dorsum the bases of the four metatarsals can be palpated, between the first and second metatarsal a hole can be felt into which a finger point can be thrust, and the tubercle of the fifth metatarsal is unduly prominent.

Walther's case was not reduced, and he believed it was better to leave it alone than to operate on it because an enucleation of the cuneiform would not influence it favorably. The functional adaptation of

[1] Glasgow Med. Jour., 1912, lxxvii, 287.
[2] Arch. de Méd. et Pharm. mil., Paris, 1911, lvii, 28.
[3] Bull. et mém. d. l. Soc. de Chir., Paris, 1912, n. s., xxxviii, 190.
[4] Ann. de la Soc. Med. Chir. de Liège, liii.

the foot gradually improves, and much i by reëducation of the movements of wal become fair. Claudot found that in 11 c luxation 8 could walk in a satisfactory n after the expiration of several years. Qu 6 unreduced cases concluded that the gradually improved; the longer the patien the functional results seemed to be.[1]

DISLOCATIONS OF THE PHALAI METATARSOPHALANGEAL

Dislocations of the great toe are the They are caused by falls, by stubbing of t or by kicks at objects. Malgaigne states of the toes, 19 were of the great toe. An and the proximal phalanx may be displ to one side, the head of the metatarsal fre

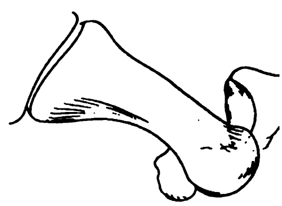


FIG. 654.—Recent backward and upward (

the plantar tissues. Cases have been rep Deal[4] and Skillern.[5] The last-mentioned on the metatarsal and as usual in this separated, one going to each side of the not interfere with reduction (Figs. 655 an

Treatment.—Reduction is made by t: similar to Farabeuf's for reduction of thu raises the toe to a right angle and makes st to push it forward, rocking it on its way. Dr. Crosby, of New Hampshire, in 1826. method for reducing these luxations b: tendon of the toe, and a hyperflexing ar on the metatarsal. This method disenga

[1] Claudot, Arch. gén. de méd. et de Pharm mil., I 1884, p. 542; Soison et Mangenot, Arch. de Méd. et quin, Arch. de Méd. et de Pharm. mil., juillet, 1895 15, p. 133; Hornus, Gaz. des Hôp., 1902, p. 412.

[2] Lancet, London, 1914, i, 213.

[4] Jour. Am. Med. Assn., 1914, lxii, 1086.

[5] Ibid., December 6, 1913, p. 2063.

[6] Canadian Med. Assn. Jour., December, 1914, N

the abductor and adductor pollicis, the long flexor, and the capsule and makes the phalanx slip over the metacarpal head, pushing these structures before it. The divided extensor tendon is then sutured and the opening in the skin closed. This method should be used only

FIG. 655.—Old dislocation backward and inward of the great toe following trauma. Note that the sesamoids are dislocated inward around the head of the first metatarsal.

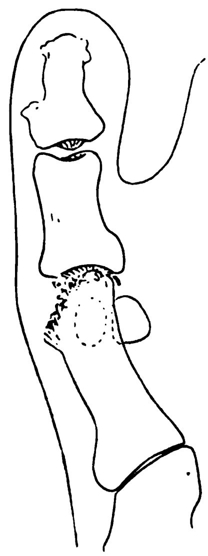


FIG. 656.—Reduction by operation of the preceding dislocation. The head of the metatarsal was trimmed off and a flap of capsule and fat was swung in between the bones as a modified arthroplasty. Note the correction. Result excellent.

after the failure of Crosby's method, which seeks to accomplish the same end without an open wound.

A few cases of dislocation of the other phalanges of the toes and the terminal phalanx of the great toe have been reported. They may be reduced by traction or transfixion and traction.

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